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Emission Characterization of an Alcohol/Diesel-Pilot Fueled Compression-Ignition Engine and Its Heavy-Duty Diesel Counterpart

Southwest Research Inst.
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16. ABSTRACT

This report describes results from emissions testing of a prototype diesel engine, developed by Volvo Truck Corporation of Sweden, which uses pilot injection of diesel fuel for compression ignition of alcohol fuel injected for main combustion. In addition to this dual-fuel engine, emission testing was also conducted on a heavy-duty diesel engine of similar design. Both engines were tested over the 1979 13-mode FTP, or shorter versions of this modal test, and over the 1984 Transient FTP as well as an experimental bus cycle. The dual-fuel engine was characterized with methanol, ethanol and ethanol with 30 percent water (wt %). An oxidation catalyst was also used with methanol and ethanol.

Emission characterization included regulated emissions (HC, CO, and NO_x) along with total particulate, unburned alcohols, individual hydrocarbons, aldehydes, phenols, and odor. The particulate matter was characterized in terms of particle size distribution, sulfate content, C, H, S, metal content, and soluble organic fraction. The soluble organic fraction was studied by determining its elemental composition (C,H,S,N), boiling point distribution, BaP content, relative make-up of polar compounds, and bioactivity by Ames testing.

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FOREWORD

The project on which this report is based was initiated by Task Specification No. 6 of EPA Contract 68-03-2884, received by SwRI on August 1, 1980. The contract was for "Basic Characterization Support for the Emission Control Technology Division." Task Specification No. 6 of that contract was specifically for the "Characterization of Emissions from Volvo Heavy-Duty Diesel and Diesel/Alcohol Engines." The work was identified within SwRI as Project No. 11-5830-006.

The Project Officer and the Branch Technical Representative for EPA's Technology Assessment Branch during the Task Specification were Mr. Robert J. Garbe and Mr. Thomas M. Baines, respectively. SwRI Project Director was Mr. Karl J. Springer, and SwRI Project Manager was Mr. Charles T. Hare. The SwRI Task Leader and principal investigator for the Task Specification No. 6 effort was Mr. Terry L. Ullman. Lead technical personnel were Mr. Richard L. Mechler and Mr. Clay D. Suhler.

We would like to express our appreciation to Volvo Truck Corporation of Sweden for supplying both the production diesel engine and the prototype alcohol engine, with diesel pilot injection. We especially appreciate the direction and assistance of Mr. Ernst Holmér and Mr. Bert-Inge Bertilsson of Volvo.

ABSTRACT

The uncertainity of petroleum-based fuel availability has created a need for diversifying into alternative fuels. Volvo Truck Corporation of Sweden has developed a prototype dual-fuel truck-size diesel engine with diesel fuel pilot injection for compression-ignition and subsequent alcohol injection for main combustion. This approach is attractive because it requires no new technology, and because the energy efficiency of the engine is retained essentially intact while consuming low-octane fuels. Exhaust emissions from this prototype dual-fuel engine were characterized with methanol, ethanol, and ethanol with 30 percent water (wt%). In addition, the effects of an oxidation catalyst on methanol and ethanol exhaust were investigated. Emissions were also measured for a heavy-duty diesel engine of similar design.

Emission characterization included regulated emissions (HC, CO, and NO_x) along with total particulate, unburned alcohols, individual hydrocarbons, aldehydes, phenols, and odor. The particulate matter was characterized in terms of particle size distribution, sulfate content, C, H, S, metal content, and soluble organic fraction. The soluble organic fraction was further studied by determining its elemental composition (C,H, S,N), boiling point distribution, BaP content, relative make-up of polar compounds, and bioactivity by Ames testing.

Exhaust emissions from the various test configurations were characterized over the 1979 13-mode Federal Test Procedure (FTP), or shorter versions of this modal test, and over the 1984 Transient FTP. In addition, regulated gaseous and particulate emissions were determined over an experimental bus cycle developed from CAPE-21 bus data.

Particulate and NO_x emissions were significantly reduced; whereas hydrocarbons and CO increased with the use of the alcohol fuels as compared to the diesel engine. Levels of aldehyde emissions were also higher with the alcohol fuel, and significant quantities of unburned alcohol were detected. The catalyst reduced unburned alcohols, HC, and CO emissions, but had little effect on total particulate as compared to levels noted for the alcohol test configurations (methanol and ethanol) without catalyst. The catalyst caused substantial conversion of the fuel sulfur (in the pilot injected diesel fuel) to sulfate. Emission levels and trends for the ethanol+water configuration were similar to those for the methanol configuration.

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I. INTRODUCTION

Worldwide dependence on petroleum products and associated economic problems have become quite apparent over the last decade. The uncertainty of petroleum-based fuel availability for transportation and production of goods and services has created a need for diversifying into alternate fuels. Alcohols constitute a renewable fuel source which has been available for years, but which has not been used as primary engine fuel because petroleum distillates were less expensive to produce. The Volvo Truck Corporation of Sweden has developed a pilot-injected diesel/alcohol engine which can utilize a broad variety of alternative fuels. The approach represented by this engine is attractive because it requires no new technology, and because the energy efficiency of the engine is retained essentially intact. Up to 85 percent of diesel fuel normally used can be replaced by an alternative fuel, depending on the load factor.

The prototype dual-fuel engine was made from a standard diesel engine by adding a small diesel injection pump and injectors for pilot injection of diesel fuel, and adjusting the standard diesel injection pump to inject alcohol fuels through the injectors normally used. Pilot injection of diesel fuel allows efficient use of low cetane fuels such as methanol, ethanol or even ethanol mixed with water.(1)* The prototype engine has been operated successfully in heavy-duty truck and bus applications, with only minor mechanical problems. It is uncertain what effects the use of alternative fuels will have on mobile source emissions, particularly those which are currently unregulated. Lower emissions of smoke and NO_x, already reported in the literature, make alcohol fuels appear to be a viable diesel fuel supplement.

The objective of this work was to characterize the emissions behavior of a Volvo truck-size (186 kW at 2200 rpm) turbocharged diesel engine, equipped with diesel fuel pilot injection for ignition and alcohol for main combustion. The emissions of this engine were compared to those from a similar conventional diesel engine. The diesel pilot/alcohol engine emissions were characterized during operation with neat methanol, neat ethanol, and ethanol mixed with water. The effects of an oxidation catalyst on methanol- and ethanol-fueled engine exhaust were also studied. Ethanol with 30 percent (by weight) water (140 proof) was studied as an alternative fuel, because direct use of ethanol containing substantial amounts of water achieves a higher total energy balance from raw material to useful work output than use of more completely distilled ethanol (near 200 proof).

Emission characterization included regulated emissions (HC,CO and

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*Superscript numbers in parentheses designate references at end of report.

NO_x) along with total particulate, unburned alcohols, individual hydrocarbons, aldehydes, phenols, and odor. In addition to these items, the particulate matter was characterized in terms of particle size distribution, sulfate content, C,H,S, and metals content, and soluble organic fraction. The soluble organic fraction was further studied by determining its elemental content (C,H,S,N), boiling point distribution, BaP content, relative make-up of polar compounds, and bioactivity by Ames testing.

Exhaust emissions from the various test configurations were characterized over the 1979 13-mode Federal Test Procedure (FTP), or shorter versions of this modal test, and over the 1984 Transient FTP. In addition, regulated gaseous and particulate emissions were determined over an experimental bus cycle developed from data derived by the Coordinating Research Council CAPE-21 project. In this CRC study, trucks and buses were instrumented and operated in typical use in Los Angeles and New York City.

The 13-mode FTP is currently used for regulatory purposes of heavy-duty diesel emissions. The transient FTP will be optional for the 1984 model year, and will be mandatory by 1985. The 1986 proposed transient FTP includes both gaseous and particulate emission measurement/regulation. Thirteen-mode FTP emission measurements were conducted during individual modes of steady-state operation. Transient FTP emission measurements were conducted during both cold-start and hot-start cycles.

II. SUMMARY

Volvo Truck Corporation of Sweden has developed a prototype dual-fuel Volvo truck-size (186 kW at 2200 rpm) engine equipped with diesel fuel pilot injection for ignition and subsequent alcohol injection for main combustion. Pilot injection of diesel fuel allowed efficient use of low-cetane fuels, while providing good performance over the entire operating range from cold start-up and idle to maximum power at rated speed. The prototype dual-fuel engine consumed only diesel fuel during light load conditions. The low-cetane, main energy fuel was added as output power demand increased.

Emissions from the dual-fuel engine were characterized during operation with neat methanol, neat ethanol, and ethanol mixed with water. The effects of an oxidation catalyst on the exhaust of the methanol- and ethanol-fueled engine was also studied. The Volvo TD-100C diesel engine was used for emission comparisons and was of the same basic model as that modified to build the dual-fuel engine (Volvo designation TD-100A). Exhaust emissions from the various test configurations were characterized over the 1979 13-mode Federal Test Procedure (FTP), or shorter versions of this modal test, and over the 1984 Transient FTP.

Table 1 summarizes the composite results from six test configurations, which include diesel, methanol, methanol with catalyst, ethanol, ethanol with catalyst, and ethanol with 30 percent water (wt %). Seven-mode composite results given in the table are from an abbreviated version of the 13-mode test procedure which does not include some of the intermediate load conditions. Detailed test results may be found in the Results section of this report (Section IV). With such a broad variety of emission measurements available for six test configurations, the level of effort alloted for sample collection and sample analysis was based on importance of useful information obtained and similarities in measured emission trends.

For the Volvo TD-100C diesel engine, both the 13-mode composite and the transient composite gaseous emission rates, as well as fuel consumption and unregulated emissions, all appear to be in ranges typical of direct-injected, turbocharged, truck-sized diesel engines. The NO_x emissions reported during this program were not corrected for engine intake air humidity due to uncertainty about validity of the correction when oxygen-containing fuels (such as alcohols) were used. For comparison purposes, NO_x values for the diesel configuration given in the table have not been corrected for intake humidity.

The emission levels were similar for both transient and steady-state test procedures, but tend to be slightly higher for the transient test procedure. Emission results from the Volvo TD-100C diesel engine serve as reference, since the Volvo TD-100A dual-fuel engine was of the same

TABLE 1. SUMMARY OF COMPOSITE EMISSION RATES FROM THE VOLVO-TD-100C DIESEL ENGINE AND THE VOLVO TD-100A DIESEL PILOT/ALCOHOL ENGINE

	Engine Test Configuration											
Composite Emission Rates	Diesel Volvo TD-100C		Methanol Volvo TD-100A		Methanol-Catalyst Volvo TD-100A		Ethanol Volvo TD-100A		Ethanol-Catalyst[a] Volvo TD-100A		Ethanol+30% Water Volvo TD-100A	
Federal Test Procedure (FTP)	13-mode	Transient	13-mode	Transient	13-mode[h]	Transient[i]	13 mode	Transient	13 mode	Transient	13-mode	Transient
Hydrocarbon, HC[b] g/kw-hr, (g/hp-hr)	1.05 (0.78)	1.15 (0.85)	1.45 (1.08)	1.95 (1.45)	0.16 (0.12)	0.22 (0.16)	1.65 (1.23)	2.27 (1.69)	0.60 (0.45)	0.63 (0.47)	1.89 (1.41)	Not Run
Carbon Monoxide, CO g/kw-hr, (g/hp-hr)	3.18 (2.37)	4.04 (3.01)	9.55 (7.12)	10.29 (7.67)	0.83 (0.62)	3.74 (2.79)	10.52 (7.84)	12.89 (9.61)	3.10 (2.31)	4.24 (3.16)	9.99 (7.45)	
Oxides of Nitrogen, NO_x[c] g/kw-hr, (g/hp-hr)	11.88[f] (8.86)	11.19 (8.34)	5.26 (3.92)	7.31 (5.45)	6.79 (5.06)	7.89 (5.89)	6.85 (5.11)	7.38 (5.50)	7.98 (5.95)	8.62 (6.43)	4.46 (3.32)	
Brake Specific Fuel Consump.[d] kg fuel/kw-hr, (lb fuel/hp-hr)	0.262 (0.431)	0.288 (0.473)	0.486 (0.799)	0.531 (0.873)	0.482 (0.792)	0.547 (0.900)	0.395 (0.650)	0.435 (0.715)	0.400 (0.657)	0.448 (0.737)	0.495 (0.814)	
Test Cycle	7-mode	Transient	7-mode	Transient	7-mode	Transient	7-mode	Transient	7-mode	Transient	7-mode	Transient
Total Individual HC mg/kw-hr	100	130	67	180	32	66	Not Run	600	Not Run	220	220	Not Run
Total Unburned Alcohols mg/kw-hr	Does Not Apply	Does Not Apply	2200	4900	950	890		2300		480	860	
Total Aldehydes[e] mg/kw-hr	19	14	88	250	140	260		240		250	91	
Total Phenols mg/kw-hr	Not Run	35	17	24	14	48		44		33	Not Run	
Total Particulate g/kw-hr, (g/hp-hr)	0.69 (0.52)	0.70 (0.52)	0.30 (0.23)	0.39 (0.30)	0.51 (0.38)	0.37 (0.27)		0.35 (0.26)		0.38 (0.28)	0.33 (0.24)	
Sulfate, $SO_4^=$ mg/kw-hr, (% of Particulate)	45 (6.5%)	38 (5.4%)	14 (4.6%)	16 (4.1%)	220 (43%)	98 (27%)		14 (4.0%)		89 (23%)	17 (5.2%)	
Soluble Organic Fraction (SOF) mg/kw-hr, (% of Particulate)	200 (28%)	220 (32%)	200 (66%)	280 (73%)	70 (14%)	60 (16%)		190 (53%)		40 (11%)	190 (58%)	
BaP µg/kw-hr	0.64	3.7	0.86	1.7	0.08	0.33		0.32		3.7	1.2	
Ames Response[j] (revertant/plate x10^3)/kw-hr	490	580	310	510[k] 180	120	710		790		2900	90	

[a] Run with backpressure device engaged during idle and motoring.

[b] HC value reported here is based on measurements by HFID. FID response is very low for unburned alcohols and other species of unregulated emissions

[c] 13-mode NO_x correction factor for intake humidity was computed but not applied

[d] Computed on the basis of measured diesel consumption and alcohol consumption combined

[e] Benzaldehyde was not included in the total composite value

[f] NO_x value is reduced to 10.89 g/kw-hr (8.12 g/hp-hr) when the intake humidity correction for NO_x is applied

[g] Phenols were determined from only selected modes

[h] Without backpressure device at idle

[i] Average of data with and without backpressure device

[j] Average of brake specific response with and without metabolic activation from all 5 strains

[k] Results from first and second group respectively

basic design.

Methanol

The dual-fuel engine was operated on methanol with no engine performance problems during either the steady-state or transient testing. The only adjustments made after initial set-up were adjustments of the alcohol injection pump to compensate for differing volumetric heating values of the alcohol fuels tested. Maximum power with methanol was set to 186 kW (250 hp) at 2200 rpm. The maximum torque obtained after adjustment was similar to that obtained from the diesel engine. Gaseous emissions of HC and CO were greater for the dual-fuel engine on methanol than for the diesel engine. Total hydrocarbon values given in Table 1 for alcohol fuel configurations are low due to low response of the HC instruments to unburned alcohols, aldehydes, and other species. Use of methanol in the dual-fuel engine increased CO by 60 percent over the diesel version. Compared to the diesel engine, NO_x emissions were reduced by 56 percent for the 13-mode cycle, and 35 percent for the transient. Brake specific fuel consumption was higher for alcohols due to the greater mass of alcohol needed to achieve power output comparable to diesel fuel.

Emission of total particulate matter dropped by approximately 50 percent when methanol was used. With less diesel fuel consumed due to substitution of methanol, total sulfur entering the engine was reduced, causing sulfate to decrease about 60 percent compared to that from the diesel engine. A significant portion of the total particulate from the methanol configuration (about 70 percent) was soluble using methylene chloride for extraction of the soluble organic fraction (SOF). As with the other configurations tested, the brake specific benzo(a)pyrene (BaP) was significantly higher for the transient composite than for the 7-mode composite. Brake specific BaP from transient operation with methanol was lower than for the diesel engine, but the BaP from the 7-mode composite was higher with the methanol than with the diesel. The average brake specific Ames response from the five strains tested with and without metabolic activation was lower for the methanol configuration than for the diesel configuration.

Methanol-Catalyst

An oxidation catalyst was also tested with the methyl alcohol as an exhaust aftertreatment device to reduce unburned alcohol and other emissions. The catalyst, manufactured by Unikat of Sweden and designated as a Type U210, was added to the engine and was not specifically optimized for the application. As expected, the catalyst reduced HC and CO emissions substantially from the levels noted in the methanol configuration. The indicated total hydrocarbons were very low for both test procedures. The catalyst was very effective in reducing unburned alcohols and some individual hydrocarbons, but appeared to have little effect on the aldehyde emissions. The CO level was reduced substantially during the 13-mode procedure, due to significant reductions in CO during the maximum torque condition and other heavy load conditions. The CO level from the transient FTP was not reduced as much, because during the transient cycle the engine is not as heavily loaded (time-weighted basis). NO_x emissions appear to have increased when the catalyst was used with methanol. Some of the additional NO_x emission noted from the transient composite was due to the use of an exhaust backpressure-increasing device, but the backpressure device was not used during the 13-mode test. The exhaust backpressure device operated during closed rack conditions. It was used as a fast warm-up aid, and to maintain higher catalyst temperature during idling or motoring conditions, by increasing the exhaust backpressure at these conditions. Transient composite fuel consumption was also increased, because the backpressure device required more diesel fuel to maintain idle speed when engaged.

Although the catalyst reduced unburned fuel-like matter and CO, the total particulate level was about the same as for the methanol configuration and 50 percent lower than the diesel particulate levels for the transient procedure. Seven-mode composite particulate actually increased by 67 percent over the methanol configuration, but was still 26 percent lower than the diesel 7-mode particulate level. Analysis of particulate composition showed that 7-mode sulfate had been increased by a factor of five over the diesel engine level, and to 15 times that of the methanol configuration. Increases in transient composite sulfate were also noted, but not to the same extent because the catalyst was cooler during the cold- and hot-start transient tests. As with hydrocarbons, the soluble organic fraction of the particulate was substantially reduced by the catalyst. The catalyst also reduced the level of BaP compared to the methanol configuration. Although reductions in SOF and BaP occurred with the catalyst, the average brake specific Ames response was significantly increased over the transient composite, where the catalyst heat may have been minimal. The Ames response for the 7-mode composite SOF was relatively low with the catalyst.

Ethanol

Methanol (CH_3OH) and ethanol (C_2H_5OH) are somewhat similar alcohols, but ethanol has a higher volumetric heating value. The dual-fuel engine's alcohol fuel injection pump was adjusted to obtain 186 kW maximum power on each alcohol. At these settings, maximum torque was about 5 percent lower with ethanol than with methanol due to the volumetric characteristics of the injection pump. Based on similar 13-mode emission trends between methanol and ethanol, only transient operation was characterized extensively.

With ethanol, HC and CO emissions were slightly higher than for the methanol configuration, but considerably higher than the diesel configuration. Aldehyde emissions were at about the same level as for methanol. Unburned alcohols were lower with ethanol, but individual hydrocarbons were about 3 times those of either the diesel or the methanol configuration. The 13-mode composite NO_x emission with ethanol was 24 percent higher than for methanol due to substantially higher NO_x emissions in the maximum power mode. Brake specific fuel consumption reflects the differences in heating values. The total particulate and sulfate emission rates from transient operation with ethanol were about 10 percent lower than from the methanol configuration. The soluble organic fraction was also somewhat lower, and the brake specific BaP level was about one fifth that of the methanol configuration. Although the BaP level was lower, the brake specific Ames response was about twice that from transient operation in the methanol configuration, and was similar to the level noted for the methanol-catalyst configuration.

Ethanol-Catalyst

When the catalyst was used with ethanol, HC and CO were reduced, but not to the same extent as for the methanol-catalyst configuration. The catalyst reduced the unburned alcohol and individual hydrocarbon levels substantially, but little effect on total aldehyde emissions was noted. The transient composite NO_x emission increased 14 percent over that from the ethanol configuration, when the catalyst and backpressure device were used. Similar to the methanol-catalyst configuration, the fuel consumption increased in the ethanol-catalyst configuration due to use of the backpressure device. Total particulate, sulfate, and SOF emissions followed the same trends as noted for the methanol-catalyst configuration. The brake specific BaP level was almost 10 times that of the methanol-catalyst configuration and was the same level as obtained from the diesel engine. The transient Ames response was the highest of any of the test configurations.

Ethanol + Water

Emissions with ethanol and 30 percent water (wt %) were very similar to emissions with methanol. If equal volumes of ethanol with 30 percent water (wt %) and methanol were injected into separate combustion chambers, the mass of individual carbon, hydrogen, and oxygen atoms in the chamber would be very nearly equivalent. Changing to ethanol with 30 percent water, from methanol, required only minor adjustments of the maximum rack stop (although a slight reduction in maximum torque was noted similar to when ethanol alone was used). This net energy-to-volume similarity would allow easy interchangeability between neat methanol and ethanol by adjusting the ethanol water content to about 30 percent (wt %). Based on 13-mode composite emissions, ethanol+water produced slightly higher HC and CO, but lower NO_x emissions than the methanol configuration. Aldehydes were about the same, but unburned ethanol was lower and IHC was higher than with the ethanol configuration. The 13-mode NO_x from the ethanol+water configuration was lowest of the six configurations tested. Thirteen-mode composite particulate emissions were very similar to the methanol configuration, and were about 50 percent lower than from the diesel configuration. The sulfate and SOF portions of the total particulate were essentially the same as for methanol. BaP content was higher than for the methanol configuration, but the 7-mode composite Ames response was lowest of all the configurations tested.

Bus Cycle

As mentioned earlier, regulated gaseous and particulate emissions were also measured during a transient bus cycle. The bus cycle includes more accelerations and decelerations, and produces 50 percent less work in 30 percent less time than the transient cycle. Emissions from the bus cycle were generally higher than those from the transient composite FTP. Bus cycle emissions followed the same trends as indicated for the transient composite results. Details of the bus cycle emissions are given in the text of the Results section of this report.

III. TEST PLAN AND DESCRIPTION OF ENGINES, FUELS, AND PROCEDURES

The intent of this program was to characterize regulated gaseous emissions along with particulate and unregulated emissions from a Volvo diesel pilot/alcohol engine run on several alcohol fuels and using an oxidation catalyst as an aftertreatment. In addition, a conventional Volvo diesel engine of similar design was to be characterized for emission comparison. This section describes the proposed test plan which was used as a guide in the program. The diesel pilot/alcohol engine and its diesel counterpart are also described. Some discussion is given to explain the operation and interaction of the diesel pilot/alcohol injection systems. Specifications for the diesel fuel and the alcohols are given along with some of their properties. Procedures are described, including the tests used to generate and acquire the emission samples, and the analytical procedures used to characterize the emission samples.

A. Proposed Test Plan

A test plan was conceived for operating both the prototype dual-fuel engine and its conventional diesel counterpart. Proposed engine/control/fuel test configurations planned for testing included the following:

Proposed Test Configurations

Engine	Fuel	Aftertreatment
Diesel/Alcohol	Methanol + pilot diesel	None
	Ethanol + pilot diesel	None
	Ethanol(70)/water(30) + pilot diesel	None
	Ethanol(70)/water(30) + pilot diesel	Oxidation catalyst
	Ethanol + pilot diesel	Oxidation catalyst
	Methanol + pilot diesel	Oxidation catalyst
Diesel	Diesel	None

The planned program included emission measurements of both regulated and unregulated emissions for each of the test configurations shown above. Each test configuration was to be tested over both steady-state and transient operation. Table 2 shows the maximum potential extent of emission characterizations. Delays, additions, and modifications occurred due to needs for preliminary data, engine operational changes, and equipment utilization. Thus, the level of effort applied to emission characterization under some test configurations was modified. Flexibility in the test plan was utilized to reduce the number of emission measurements required in some configurations, on the basis of useful emission information obtained, and similarities of measured emissions trends.

TABLE 2. PLANNED EMISSION MEASUREMENTS FOR CHARACTERIZATION OF VOLVO TEST ENGINE

Exhaust Constituent(s) Measured or Characterized	Test Sequences									
	Transients				13-Mode		Seven (7) Extended Modes	(Full) Power Curve	Bus Transients	
	Cold		Hot							
	1	2	1	2	1	2			1	2
Visible Smoke, 2 meters[a]					✓			✓		
Regulated Gaseous Emissions	✓	✓	✓	✓	✓	✓	✓		✓	✓
O_2					✓	✓	✓			
Unburned Alcohols	✓		✓				✓[b]		✓	
Individual Hydrocarbons	✓		✓				✓			
Aldehydes	✓	✓	✓	✓			✓[b]		✓	
Phenols	✓		✓				✓			
Odor Index, DOAS	✓		✓				✓		✓	
Particulate Characterization										
Mass	✓	✓	✓	✓			✓[b]		✓	✓
Size Distribution	✓		✓				✓			
C, H, N, S, & O	✓		✓				✓			
Metal content	✓		✓				✓[b]			
Sulfate	✓		✓				✓[b]			
Characterization of Solubles in Particulate										
Mass	✓	✓	✓	✓			✓[b]		✓	✓
Boiling Range	✓		✓				✓			
BaP	✓	✓	✓	✓			✓			
Ames Bioassay	✓	✓	✓	✓			✓			
HPLC Fractionation[c]	✓		✓				✓			
C, H, N, S, & O	✓		✓				✓			

[a] should run Federal Smoke, too, if a part of testing done on appropriate dyno

[b] also measured during other six modes of 13-mode, not on extended basis

[c] limited to quantitative determinations of aromatic, transitional, and oxygenated fractions

All the planned test configurations were characterized to some extent, except ethanol and water with pilot diesel and oxidation catalyst. Emission characterization included regulated emissions (HC,CO and NO_x) along with total particulate, unburned alcohols, individual hydrocarbons, aldehydes, phenols, and odor. In addition to these items, the particulate matter was characterized in terms of particle size distribution, sulfate content, C,H,S, and metals content, and soluble organic fractions. The soluble organic fraction was further characterized by determining its elemental content (C,H,S,N), boiling point distribution, BaP content, relative make-up of polar compounds, and its bioactivity by Ames testing.

B. Description of Test Engines

The diesel engine, shown in Figure 1, was designated as a Volvo TD-100C. It is a direct-injected, turbocharged diesel engine which produces 186 kW (250 hp) at 2200 rpm. Figure 2 shows the diesel pilot/alcohol engine, or dual-fuel engine, which was designated as a Volvo TD-100A. The dual-fuel engine is essentially a TD-100 series modified to accept low-cetane fuels by utilizing pilot injection of diesel fuel. Some of the specifications common to both engines are given in Table 3.

TABLE 3. SPECIFICATIONS FOR THE VOLVO
SERIES TD-100 ENGINE

Maximum Output	186 kW (250 hp) at 2200 rpm
Maximum Torque	915 N•m (686 ft lbs) at 1400 rpm
No. Cylinders	6
Bore	120.65 mm (4.750 inches)
Stroke	140.00 mm (4.112 inches)
Displacement	9.6 liters (586 in.^{3})
Compression Ratio	15:1
Maximum Idle	2400 - 2500 rpm
Minimum Idle	475 - 525 rpm
Turbocharger Boost	80 - 100 kPa (11.5 - 14.2 psi)
Firing Sequence	1-5-3-6-2-4
Direction of Rotation	Clockwise (from front)

The pilot diesel fuel is injected through an additional fuel system. This pilot diesel fuel system consists of a relatively small distributor-type injection pump (shown on the left side of Figure 3) and single hole injectors, one for each cylinder, oriented at the outer limit of the combustion chamber in the piston crown as shown in Figure 4. The main fuel, a low-cetane fuel like methanol, is injected through the "original fuel system," utilizing an inline injection pump and four-hole injectors centrally located in the combustion chambers. The "original fuel system" has been modified to provide for the necessary capacity to inject fuel with lower energy per unit volume and still obtain rated power.

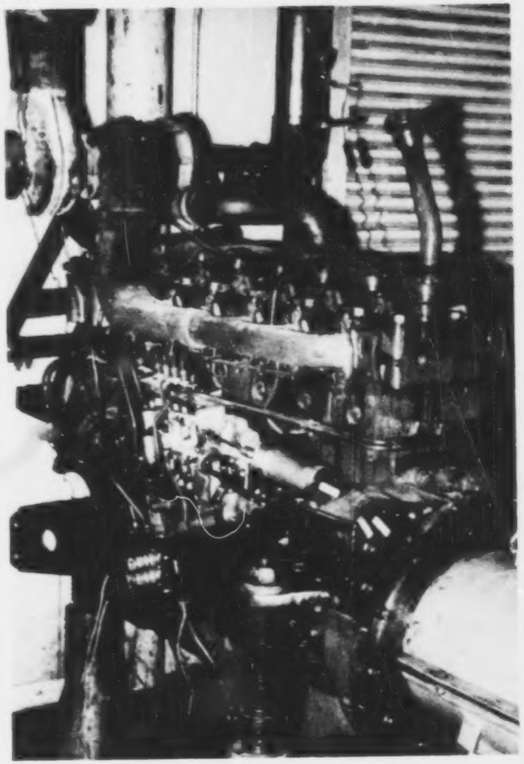


Figure 1. Volvl TD-100C heavy-duty diesel truck engine

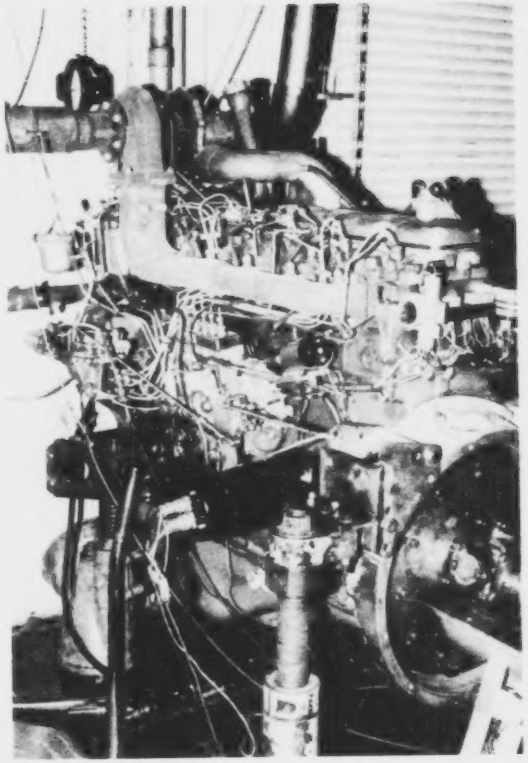


Figure 2. Volvo TD-100A heavy-duty dual-fuel truck engine

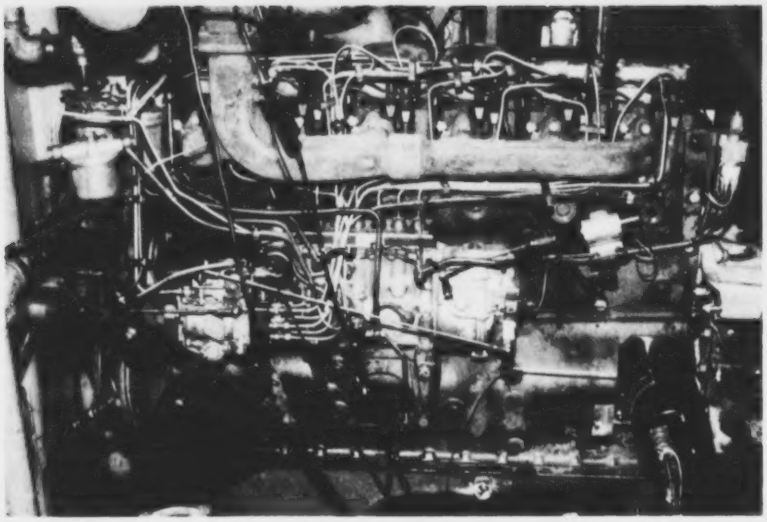


Figure 3. Arrangement of the injection pumps on the dual fuel Volvo TD-100A

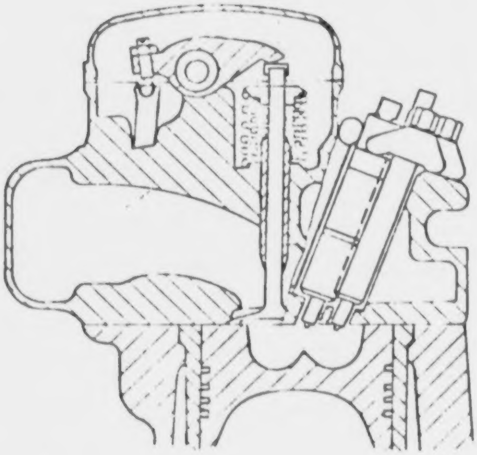


Figure 4. The cylinder head with two injectors

The fuel rate is controlled by an aneroid which senses the inlet manifold pressure, to avoid overfueling at low engine speeds. At low loads, only diesel fuel is injected. A critical point is that at which the alcohol fuel begins to be injected as the load is increased. If the quantity of diesel fuel injected is too low, HC emissions will be high. Too much diesel fuel, however, will result in smoke. The diesel fuel is injected against the air swirl so that the fuel droplets are picked up and carried around the center of the cylinder by the air, forming a rich air/fuel zone and preventing the fuel from hitting the wall of the combustion chamber in the piston (Figure 5).(1)

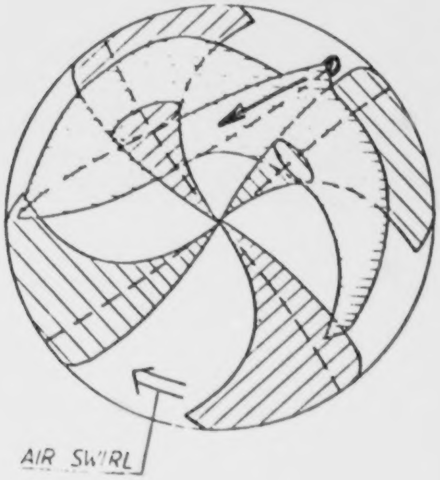


Figure 5. The fuel jets in the combustion chamber

The dual-fuel engine is operated in a manner similar to a conventional diesel engine. Cold start-up operation calls for the use of a preheater in the intake air system, prior to and after cold-start cranking. Activating the ignition switch energizes the preheater for 50 seconds before the engine is cranked. The preheater is located in the connecting pipe between the turbocharger and the intake manifold. Upon starting, the preheater is re-energized for 50 seconds or until the water temperature reaches 50°C (122°F), whichever occurs first. Solenoid actuators are used on both fuel injection pumps, as shown in Figure 3. During the preheat mode and cranking, the alcohol fuel pump is held to the "OFF" fuel position to prevent quenching of cold-start combustion by the alcohol. Simultaneously, the diesel pump is held to "ON", or to the "high flow" position. After the engine has started and the second phase of preheat has expired, the alcohol fuel pump is switched to the "ON" fuel position and will deliver fuel on rack demand. As soon as the rack (located on the alcohol pump) is moved from the idle position, electrical contact is broken and the diesel pump is switched to "OFF", or to the "low flow" position, in anticipation of demand for alcohol injection. Variations of this "recommended cold-start procedure" were used during emission test work. These variations will be described later in the report.

An oxidation catalyst, manufactured by Unikat AB of Sweden, was supplied in order to investigate its effect on emissions, especially unburned fuel and particulate. The catalyst, which weighed 41 kg and contained 15dm^3 (915 in.^{3}) of catalytic compound, was designated as a Type U210. The catalyst had been chassis tested for about 50 hours of operation prior to use in this program. The catalyst was installed approximately 61 cm (2 ft) downstream of the turbocharger exhaust outlet. After part of the planned testing had been completed, it was decided that a backpressure-increasing device should be used to promote faster catalyst warm-up during the transient cycle test work. Figure 6 shows the installation of the catalyst along with the backpressure device, which is mounted on the turbocharger outlet. The pipe connecting the backpressure device to the catalyst was insulated in order to retain as much exhaust heat at the catalyst as possible.

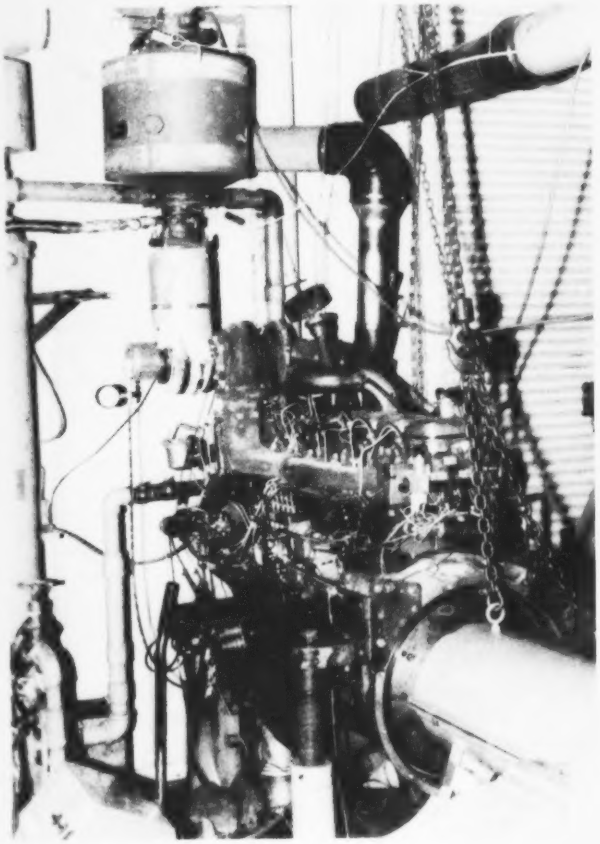


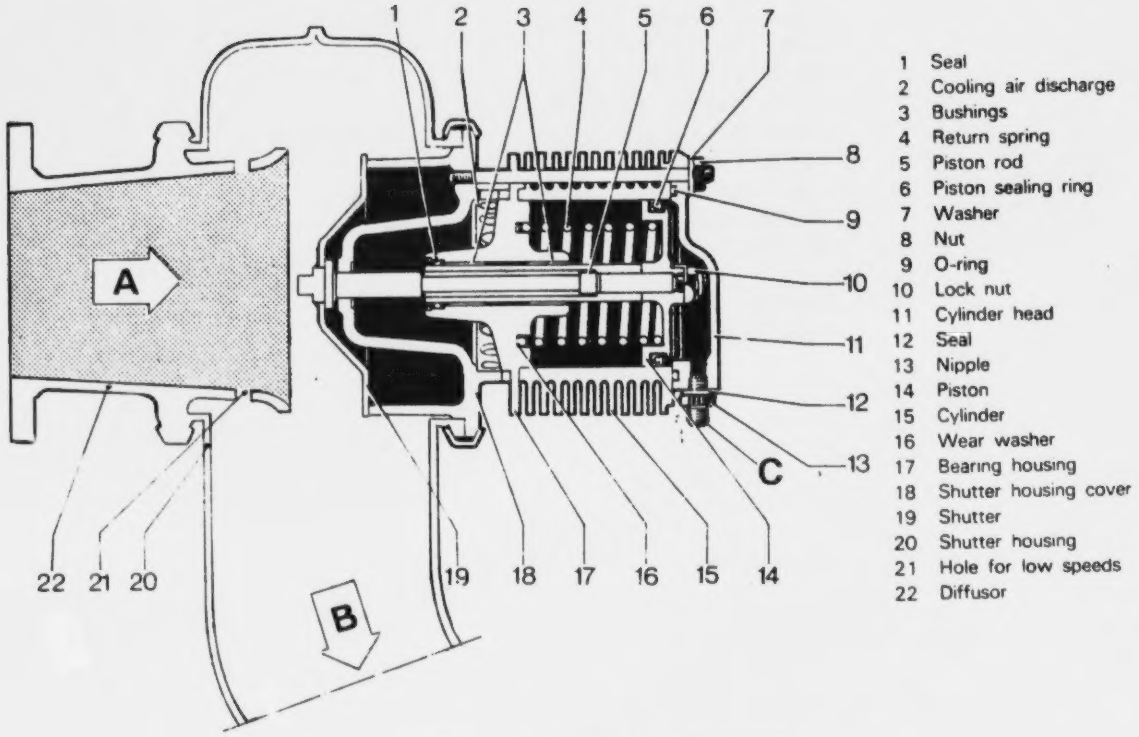
Figure 6. Installation of catalyst with backpressure device

The backpressure device, illustrated in Figure 7, is typically installed as a fast warm-up device for cold start-up, and is also used as an exhaust brake. For test purposes with the catalyst, the device was activated by electrical contact only during closed rack operation, which included idle conditions during steady-state operation and idle plus "cut throttle" operation during transient testing. When activated, the device restricts exhaust flow, forcing the engine to work against a backpressure and reducing air intake so that combustion temperature and exhaust temperature rise. Activation of the device increases the backpressure at idle from virtually atmospheric pressure to 50 kPa (7 psig) and increases the maximum backpressure from 13 kPa (2 psig) to 150 kPa (21 psig) at "high idle" speed.(2)

C. Descriptions of Test Fuels

Fuels required for the Volvo characterization program included No. 2 diesel fuel, commercial methanol, and commercial (denatured) ethanol. Analyses of the three fuels are given in Tables 4 through 6. The diesel fuel used throughout the test work was a 2D Emissions Test fuel, meeting the specifications found in the Federal Register for such fuels.(3) The methanol was obtained commercially from DuPont in drums, and was at least 99.9 percent methanol. The commercial ethanol used was composed of about 1 part methyl isobutyl ketone, 1.4 parts ethyl acetate, and 1 part unleaded gasoline per 100 parts "alcohol" (predominantly ethanol). A sample of this commercial mixture was checked for miscibility with water at water levels exceeding 35% by volume, with good results. This denatured ethanol was procured in drums. The dual-fuel engine was also operated on ethanol and 30 percent water (by weight). The ethanol and water blend was mixed in 50 gallon batches, consisting of 106.0 lbs of water to 249.5 lbs of ethanol, and mechanically agitated for 15 minutes. This fuel blend will be referred to in this text as "ethanol + water".

Table 7 compares some of the properties of the various fuels used in this program. Properties for diesel fuel, methanol, and ethanol are documented in various sources. Properties of "ethanol + water" were calculated on the assumption that the ethanol and water were consumed in the combustion chamber in the same manner as if the fuel blend were introduced as a fuel compound. Of the four fuels listed, diesel fuel has the highest heating value and cetane number, followed by ethanol, then methanol. Similarly, diesel fuel has the highest stoichiometric A/F ratio, followed by ethanol, methanol, and ethanol + water. This order of fuel properties can also be seen for flash point, heat of vaporization, H/C mole ratio, O/C ratio, and percent of fuel carbon. The properties of methanol and "ethanol + water" are very similar. The four fuels all have different liquid densities, and this property should be noted in that some of the emissions will be presented in terms of measured fuel usage.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21
22
A
B
C
1 Seal
2 Cooling air discharge
3 Bushings
4 Return spring
5 Piston rod
6 Piston sealing ring
7 Washer
8 Nut
9 O-ring
10 Lock nut
11 Cylinder head
12 Seal
13 Nipple
14 Piston
15 Cylinder
16 Wear washer
17 Bearing housing
18 Shutter housing cover
19 Shutter
20 Shutter housing
21 Hole for low speeds
22 Diffusor

Exhaust Pressure Governor

A. From exhaust turbine
B. To catalyst
C. Throttle position actuated 390 kPa (55 psig) compressed air connection

Figure 7. Volvo exhaust backpressure device used with catalyst

TABLE 4. ANALYSIS OF AMOCO 2D EMISSIONS FUEL, EM-465-F

Cetane Number	44.
Cetane Index	45.8
Gravity, °API	34.5
D-86 50% pt. °F	498
Density, g/mℓ	0.852
Cloud point, °C (°F)	--
Flash point, °C (°F)	58 (136)
Viscosity, cs	2.42
Gum, mg/100 mℓ	13.6
Total solids, mg/mℓ	--
Metals in fuel, X-ray	--
Carbon, %	87.0
Hydrogen, %	12.7
Nitrogen, ppm	166
Sulfur, %	0.24
Aromatics, %	28.4
Olefins, %	1.0
Saturates, %	70.6
Distillation, D86, °C (°F)	
IBP	168 (334)
5% point	200 (392)
10% point	213 (416)
20% point	229 (444)
40% point	250 (482)
60% point	270 (518)
80% point	296 (564)
90% point	313 (596)
95% point	329 (624)
EP	342 (648)

TABLE 5. DUPONT SPECIFICATION AND TYPICAL ANALYSIS OF METHANOL FUEL, EM-469-F

Comments	Specification	Typical Analysis
Methanol, wt %	min. 99.85	99.98
Specific gravity (25/25C)	--	0.78891
Distillation range (1 atm) First drop to dry, C	max. 1.0	0.5
Nonvolatiles, wt %	max. 0.0005	<0.0001
Acetone, wt %	max. 0.002	<0.0014
Acidity (as acetic acid), wt %	max. 0.0020	0.0013
Alkalinity (as ammonia), wt %	max. 0.00030	<0.00005
Carbonizable substances, platinum cobalt scale (APHA)	max. 35	10
Permaganate test, minutes	min. 50	56
Color, platinum cobalt scale (APHA)	max. 5	0
Hydrocarbon test, clouding when diluted with 2 parts water	none	Passes

TABLE 6. "SYNASOL" SOLVENT UNION CARBIDE SPECIFICATION AND ANALYSIS OF ETHANOL FUEL, EM-466-F

Comments	Specification	Analysis	
Specific gravity	0.789-0.793 @ 20/20°C	0.7911	20/20°C
Distillation, 760 mm	IBP 74.5 °C minimum	76.4	°C
	DP 79.5 °C maximum	78.7	°C
Acidity	0.005% wt. max., calc. as acetic acid	0.002	WTP
Ethyl Acetate	1.15 to 1.45% wt.	1.45	WTP
Water	0.50% wt. max.	0.08	WTP
Color	15 platinum-cobalt, max.	5	PTC
Odor	Mild and non-residual	"APPROVED"	
Suspended Matter	Substantially free	"APPROVED"	

TABLE 7. PROPERTIES OF FUELS USED IN THE VOLVO PROGRAM

Property	Units	Diesel	Methanol	Ethanol	Ethanol + Water[a]
Liquid Density	kg/m^3	852	796	794	868[b]
Boiling Point(s)	°C	168 - 342	65	78	N.D.[c]
Flash Point	°C	58	11	21	N.D.
Lower Heating Value	MJ/kg	42.8	19.7	27.0	18.9
Heat of Vaporization	KJ/kg	300	1100	840	1260
Stiochiometric A/F Ratio		14.6	6.4	9.0	6.3
Cetane Number		45	3	8	N.D.
Lower Heat Values	MJ/dm^3	36.5	15.7	21.4	16.2
H/C Mole Ratio		1.66-1.85	4.00	3.00	4.10
O/C Mole Ratio		0	1.00	0.50	1.05
Percent Fuel Carbon		86-88	37	52	37

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[a] "Ethanol + water" represents neat ethanol mixed with 30 percent by weight water
Properties calculated on the assumption that the ethanol + water mixture is consumed as a compound

[b] calculated from API gravity

[c] not determined

D. Test Procedures

Emissions from the Volvo TD-100C diesel engine and the Volvo TD-100A dual-fuel engine were measured during both steady-state and transient engine exercises. Steady-state operation and measurement techniques were based on the 1979 13-mode Federal Test Procedure (FTP). Transient operation and measurement techniques were based on the 1984 FTP and 1986 Proposed FTP, which includes particulate.

The 13-mode test procedure is an engine exercise which consists of 13 individual modes of steady-state operation. Starting with a fully warmed engine, the first mode is an idle condition. This idle is then followed by 2, 25, 50, 75, and 100 percent load at intermediate speed followed by another idle mode, then to rated speed - 100, 75, 50, 25, and 2 percent of full load, followed by a final idle mode. Intake air, fuel, and power output are monitored along with other data to be used in calculating modal emission rates. A 13-mode composite emission rate is calculated on the basis of modal weighting factors as specified in the Federal Register.(4)

Most unregulated emissions were measured over 7 modes of steady-state operation instead of 13 modes. This 7-mode procedure is a variation of the 13-mode procedure and consists of only the 2, 50, and 100 percent loads at intermediate and rated speeds, plus one idle condition.

On the basis of the 13-mode FTP weighting factors, 7-mode composite emissions were computed using weighted factors. Table 8 shows the respective weighting factors used. As the number of modes decreases, each modal point represents more time in mode and a wider range of power; thus the weighting for each of the 7 modes must be increased compared to its factor for 13-mode use. For both the 13-mode and the 7-mode procedures, the idle condition accounts for 20 percent of the composite value (equivalent to 20 percent of operating time).

TABLE 8. LISTING OF 13-MODE AND 7-MODE WEIGHTING FACTORS

13-Mode			7-Mode	
Mode	Engine Speed/Load, %	Wt. Factor	Mode	Wt. Factor
1	Idle	0.067		
2	Intermediate/2	0.080	1	0.12
3	Intermediate/25	0.080		
4	Intermediate/50	0.080	2	0.16
5	Intermediate/75	0.080		
6	Intermediate/100	0.080	3	0.12
7	Idle	0.067	4	0.20
8	Rated/100	0.080	5	0.12
9	Rated/75	0.080		
10	Rated/50	0.080	6	0.16
11	Rated/25	0.080		
12	Rated/2	0.080	7	0.12
13	Idle	0.067		
	Composite	1.000	Composite	1.00

Transient engine operation was performed in accordance with the 1984 Transient FTP for Heavy-Duty Diesel Engines.(4) The procedure specifies a transient engine exercise of variable speed and load, depending on the power output capabilities of the test engine. The cycle requires relatively rapid dynamometer control, capable of loading the engine one moment and motoring it the next. The system used in this program consisted of a GE 200 hp motoring/250 hp absorbing dynamometer coupled to a Midwest 500 hp eddy current (absorbing) dynamometer, with a suitable control system fabricated in-house.

The 1984 Transient cycle is described in the Federal Register by means of percent maximum torque and percent rated speed for each one-second interval, for a test cycle of 1199 seconds duration. The 20-minute transient cycle, developed from heavy-duty truck data, is composed for four five-minute segments. The four segments are described below:

Transient Cycle	
Segment	Time, sec.
New York Non-Freeway (NYNF)	297.
Los Angeles Non-Freeway (LANF)	300.
Los Angeles Freeway (LAF)	305.
New York Non-Freeway (NYNF)	297.

In order to generate the transient cycle for the Volvo engine, the engine's full power curve was obtained from 400 rpm to maximum no load engine speed.

Data from this "power curve", or engine map, was used in conjunction with the specified speed and load percentages to form the transient cycle. A graphic presentation of the speed and torque commands which constitute the FTP transient cycle used for the Volvo TD-100C diesel engine is given in Figure 8. The resulting cycle work was 11.68 kW hr (15.66 hp hr) based on a peak torque of 880 N•m (650 ft lbs) and a rated speed of 2200 rpm. The relatively large negative torque commands shown in the figure are to insure that the "throttle," or rack control, goes closed for motoring operation.

A Transient FTP Test consists of a cold-start transient cycle and a hot-start transient cycle. The same engine control or command cycle is used in both cases. For the cold-start, the diesel engine was operated over a "prep" cycle, then allowed to stand overnight in an ambient soak temperature of 20 to 30°C (68 to 86°F). The cold-start transient cycle begins when the engine is cranked for cold start-up. Upon completion of the cold-start transient cycle, the engine is shut down and allowed to stand for 20 minutes. After this hot soak period, the hot-start cycle begins with engine cranking.

All engines react somewhat differently to the transient cycle commands due to both cycle and engine characteristics. In order to judge how well the engine follows the transient cycle command, engine responses are compared to engine commands and several statistics are computed. According to the Federal Register, the following regression line tolerances should be met:

REGRESSION LINE TOLERANCES

	Speed	Torque	Brake Horsepower
Standard Error of Estimate (SE) of Y on X	100 rpm	13% of Maximum Engine Torque	8% of Maximum Brake Horsepower
Slope of the Regression Line, M	0.970 1.030	0.83-1.03 Hot 0.77-1.03 Cold	0.89-1.03 (Hot) 0.87-1.03 (Cold)
Coefficient of Determination, R^2	0.9700 1/	0.8800 (Hot) 1/ 0.8500 (Cold) 1/	0.9100 1/
Y Intercept of the Regression Line, B	±50 rpm	±15 ft lbb	±5.0 of brake horsepower
1/ Minimum			

In addition to these statistical parameters, the actual cycle work produced should not be more than 5 percent above, or 15 percent below, the work requested by the command cycle.

If the statistical criteria are not met, then adjustments to throttle servo linkage, torque span points, speed span points, and gain to and from error feedback circuits can be made in order to modify both the engine output and the dynamometer loading/motoring characteristics. After completion of the cold-start and the hot-start transient cycles, transient composite

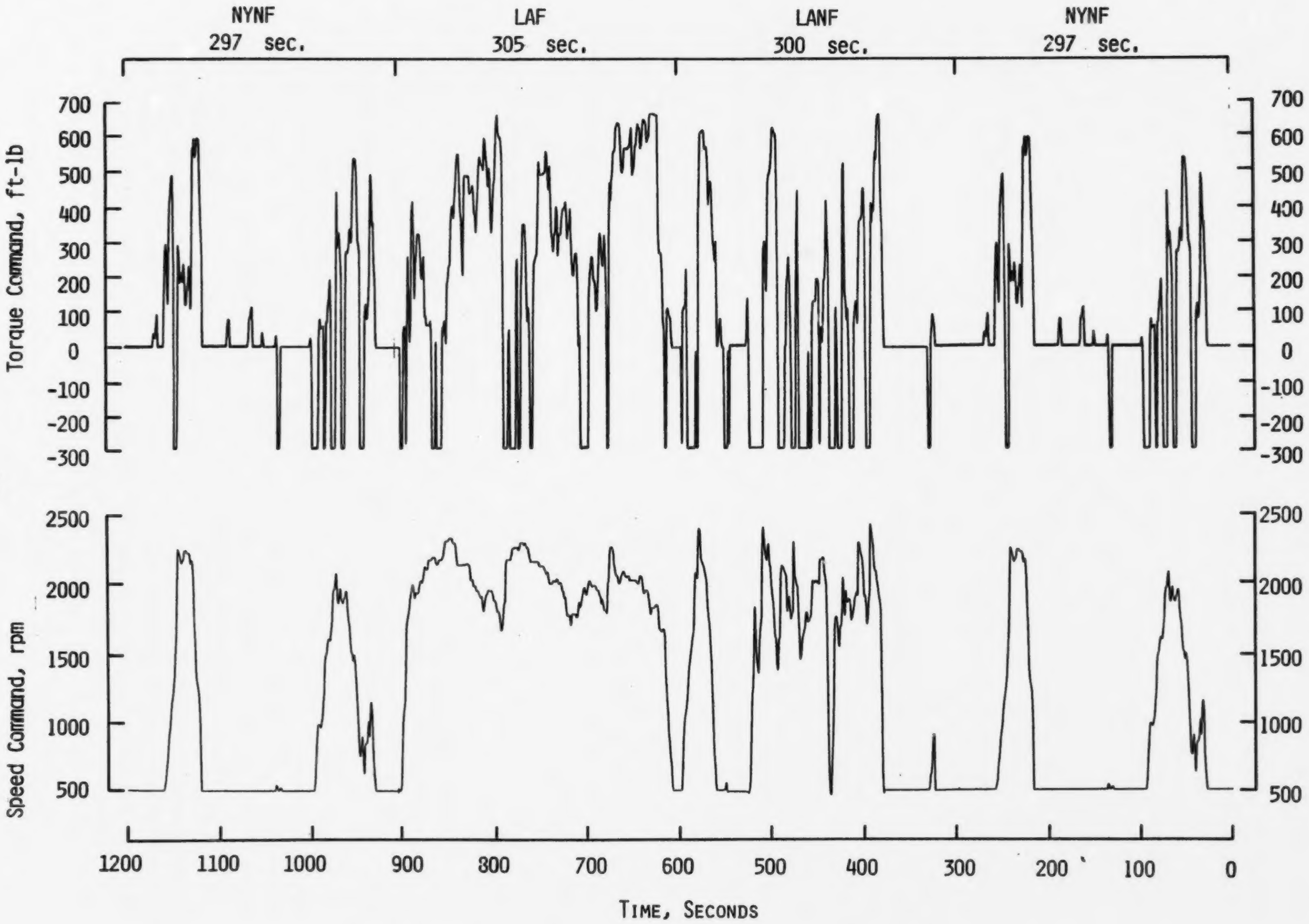

Figure 8. Graphic representation of torque and speed commands for the 1984 Transient FTP cycle based on a power map of the Volvo TD100C diesel engine

emission results are computed by the following:

$$\text{Brake Specific Emissions} = \frac{1/7\ (\text{Mass Emission, Cold}) + 6/7\ (\text{Mass Emission, Hot})}{1/7\ (\text{Cycle Work, Cold}) + 6/7\ (\text{Cycle Work, Hot})}$$

Similar to the 1984 Transient FTP cycle which was developed from heavy-duty truck data, a bus cycle was developed from CAPE-21 bus data. The bus cycle was first introduced as a research test cycle during the heavy-duty diesel baseline test work.(15) It was used in this program to indicate emission trends from the Volvo test engines in city bus applications. The 833 second transient bus cycle is composed of three segments, as shown below. A listing of the speed and torque cycle schedule is given in Reference 15. A graphic presentation of the speed and torque commands which constitute the bus cycle used for the Volvo TD-100C diesel engine is given in Figure 9. The resulting cycle work was 5.57 kW hr (7.47 hp hr) based on a peak torque of 880 N•m (650 ft lbs) and a rated speed of 2200 rpm. The bus cycle was run only as a hot-start test cycle, and was always preceded by a 20-minute soak.

Bus Cycle

Segment	Time, seconds.
New York Combined	273
Los Angeles Combined	287
New York Combined	273

The engine was also operated over the 1979 Smoke FTP exercise.(4) It essentially consists of a 5-minute idle followed by full throttle acceleration to rated speed, and finally, a full throttle lug-down from rated speed to intermediate speed. This transient smoke test cycle was run only for the measurement of smoke emissions.

During steady-state or modal engine exercises, regulated and some unregulated gaseous emissions can be sampled from the raw exhaust stream since a representative and proportional sample can be obtained. Obtaining proportional samples during transient engine operation requires the use of a constant volume sampler (CVS). Figure 10 shows the basic layout of the double-dilution CVS used to comply with the 1984 Transient FTP and the 1986 Proposed Transient FTP(5), which includes the measurement of particulate. All transient cycle test work during this program was conducted with a main dilution tunnel flow of 2000 SCFM, which provided approximately a 4:1 cycle dilution ratio of the total exhaust introduced. Regulated and unregulated gaseous emission samples were taken from the main dilution flow. Particulate-related samples required that a portion of the dilute exhaust from the main tunnel be diluted further, to an overall dilution of 12:1. The small double-dilution tunnel was operated at approximately 4 SCFM total flow in order to collect particulate on two 90 mm TA60A20 Pallflex filters in series. Weight gains from these two filters were used to determine the total particulate mass emission from the engine. The large double-dilution tunnel was operated at approximately 375 SCFM total flow, in order to accumulate large particulate samples on

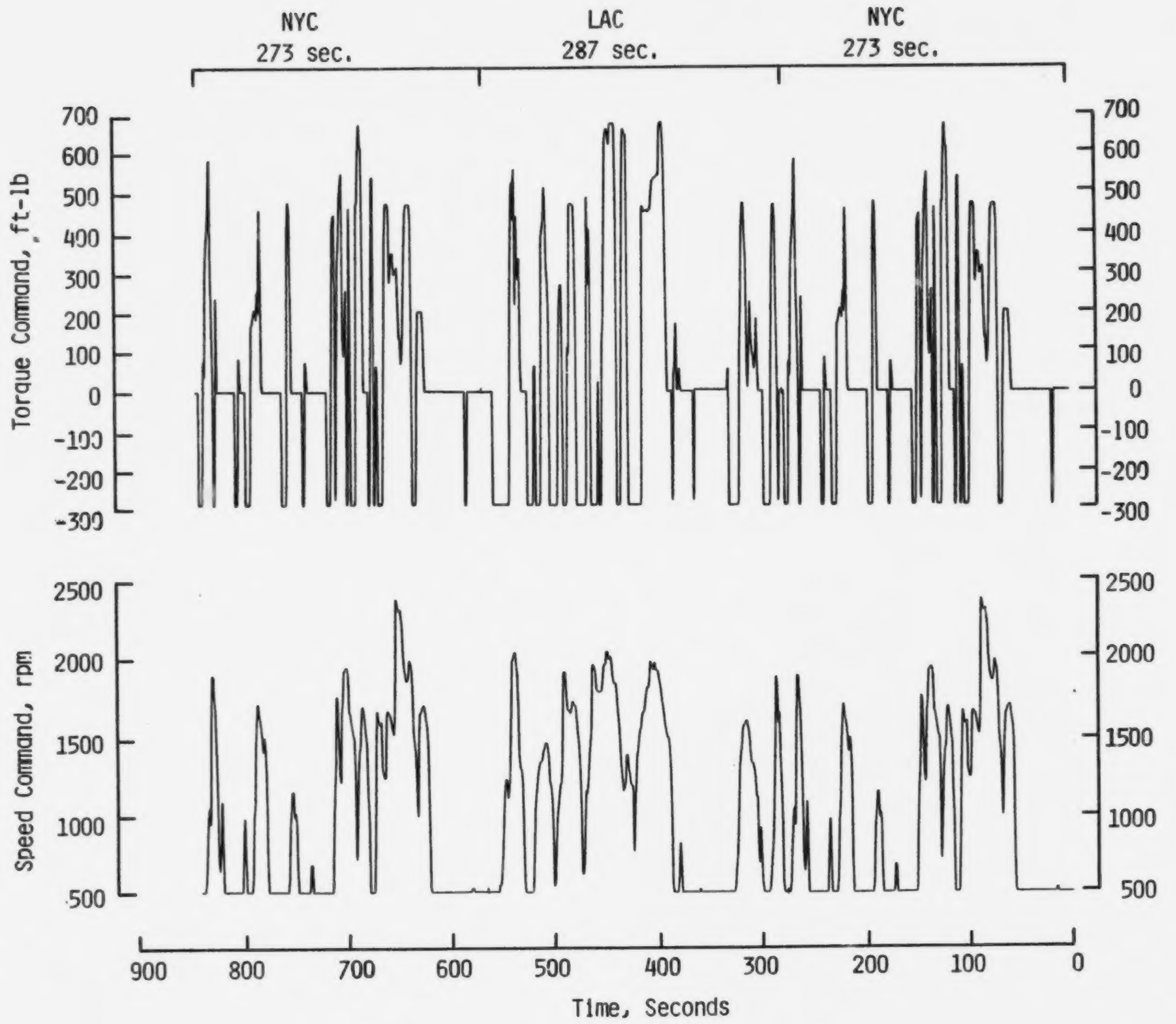

Figure 9. Graphic representation of torque and speed commands for the bus cycle based on a power map of the Volvo TD100C diesel engine

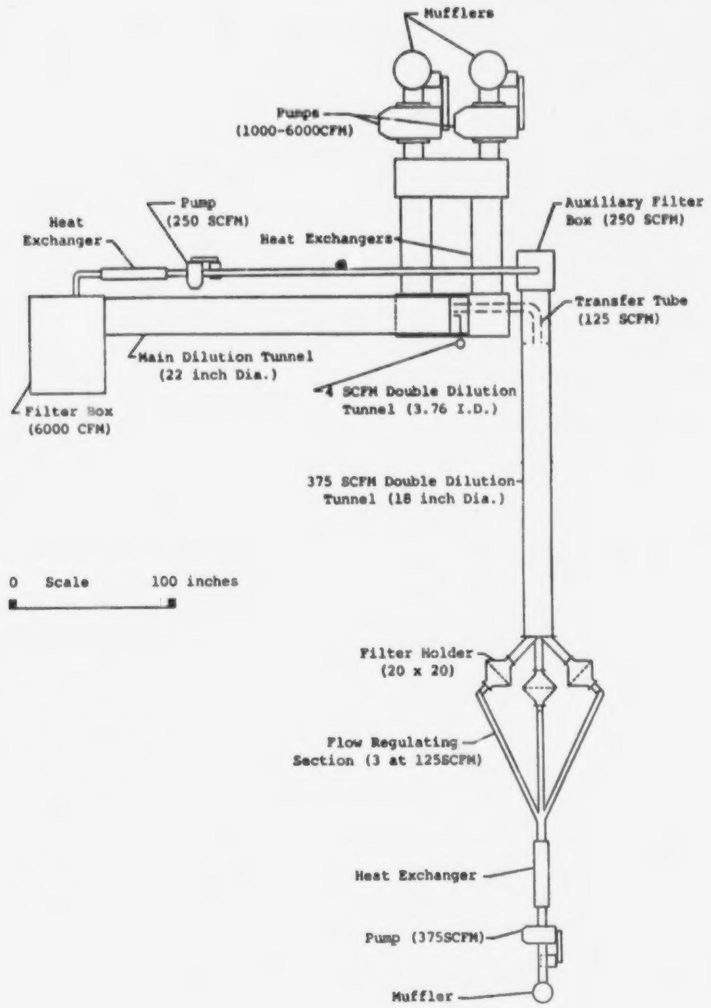
Mufflers
Pumps (1000-6000CFM)
Heat Exchanger
Pump (250 SCFM)
Heat Exchangers
Auxiliary Filter Box (250 SCFM)
Transfer Tube (125 SCFM)
Main Dilution Tunnel (22 inch Dia.)
4 SCFM Double Dilution Tunnel (3.76 I.D.)
Filter Box (6000 CFM)
375 SCFM Double Dilution Tunnel (18 inch Dia.)
0 Scale 100 inches
Filter Holder (20 x 20)
Flow Regulating Section (3 at 125SCFM)
Heat Exchanger
Pump (375SCFM)
Muffler

Figure 10. Basic layout of transient cycle heavy-duty diesel CVS with large double dilution sampler for three 20x20 inch filters

three 20x20 inch filters. It also provided auxiliary particulate sampling stations for smaller 47 mm filters. This same CVS system was used to collect particulate samples from steady-state operation of the Volvo diesel engine, by altering the main dilution tunnel flow to accommodate the total exhaust from the engine without exceeding 52°C (125°F) at the particulate filter face.

Particulate samples and other emission measurements from steady-state operation of the Volvo dual-fuel engine were obtained from a steady-state test facility which utilizes a single-dilution CVS having a capacity ranging from 1,000 to 12,000 SCFM. Figure 11 shows the sample collection end of this 1.16 m (46 in.) diameter, 17.4 m (57 ft) long stainless steel single-dilution CVS tunnel. The steady-state facility also incorporates an exhaust diverter valve which allows the engine operating condition to be stabilized before the exhaust is diverted to the CVS for particulate collection. Power absorption is provided by a Midwest 500 hp eddy current dynamometer and its associated controller. The controller was needed in order to maintain steady-state operation, especially at the 1400 rpm maximum torque condition since the dual-fuel engine's torque curve fell off sharply below 1500 rpm.

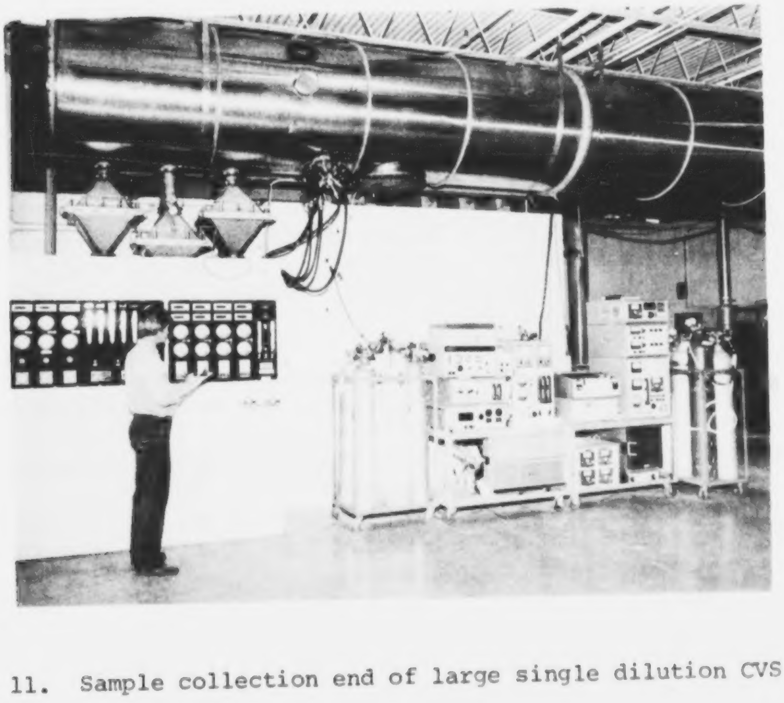

Figure 11. Sample collection end of large single dilution CVS tunnel

E. Analytical Procedures

The analytical systems used for each category of emission measurements are described in this section. The section is divided into two groups, the first dealing with gaseous emissions characterization and the second with total particulate emissions and the constituents of the total particulate. Gaseous emissions included HC, CO, CO_2, NO_x, and some unregulated pollutants. Unregulated gaseous emissions include individual hydrocarbons, aldehydes, phenols, unburned fuel, and odor. Particulate emissions included determination of the total particulate rate, and its content of sulfate, metals, carbon and hydrogen. The size distribution of the particles was measured, as well as the fraction soluble in methylene chloride. This soluble fraction was characterized for carbon, hydrogen, sulfur, nitrogen, BaP content, boiling point distribution, fractionation (by relative molecular polarity), and bioactivity by the Ames test.

1. Gaseous Emissions

Regulated gaseous emissions of HC, CO, and NO_x were measured according to the 1979 13-mode FTP and the 1984 transient FTP. The regulated emissions along with CO_2 were determined from raw exhaust samples taken during the 13-mode steady-state procedure. These same four constituents were determined in dilute exhaust samples taken during the transient procedure. The transient procedure requires that CO and CO_2 be determined from bag samples of dilute exhaust, and provides that NO_x may be determined from the same dilute sample bags or from integration of continuous NO_x concentration monitoring. For this program, the continuous NO_x, measured by chemiluminescence, was used to determine the NO_x emissions. The same instrument was used for both the 13-mode raw exhaust measurement and for the transient continuous dilute sample taken from the main dilution tunnel. Although the transient procedure only specifies one dilute exhaust Tedlar sample bag, the system used in this program uses one sample bag for each segment. This allows a better understanding of individual cycle segment contributions to the total emissions measured. Another CL instrument was used to measure NO_x from the dilute bag sample, but this reading has typically been 10 percent lower than indicated by continuous NO_x measurement techniques.(15)

Carbon monoxide and CO_2 were measured during both engine test procedures using non-dispersive infrared detector (NDIR) instruments. The CO measurement is of interest in both procedures because it is a regulated pollutant. The CO_2 measurement is of interest because it is used in the calculation of fuel usage by carbon balance along with the CO and the HC emissions. Both CO and CO_2 are determined from the raw exhaust during the 13-mode procedure and are determined from dilute exhaust bag samples during the transient test procedures.

Hydrocarbons were measured during both test procedures using the specified heated sample train and heated flame ionization detector (HFID), a Beckman 402 HFID. As with other gaseous emissions, HC measurements during steady-state procedures were taken from raw exhaust, and measurements during transient procedures were taken from the dilute exhaust. During transient test procedures, a continuous dilute sample taken from the main dilution tunnel was integrated for total hydrocarbons.

The heated HC probe and overflow calibration technique used in total HC measurements are unique to the heavy-duty transient FTP. Details as to the measurement of the regulated gaseous emissions may be found in Reference 4 for the 13-mode procedure, and in Reference 3 for the transient procedure.

The intent of both procedures is to determine the "total" HC emissions from the test engines. It is generally assumed that the exhaust hydrocarbons emitted from a diesel engine are of the same general composition as the parent fuel. The total is based on the indication from HFID instruments. It has been shown in References 6 and 7 that FID response to various species of alcohols, individual hydrocarbons, aldehydes, and phenols often differs from response to fuel-like constituents, and is affected by oxygen synergism and physical construction of the FID. Some reported FID response factors given in Reference 6 are repeated in Table 9.

Both Federal Test Procedures mentioned above also specify methods of emissions computations. In making accommodations for this project, modification to these emissions computations had to be incorporated in order to account for the dual-fuel combustion. The 13-mode data reduction calculations involve intake airflow rate and both measured and computed fuel rate, with measured emissions, to compute composite emissions rates. Equations for calculation of fuel/air ratio are based on the combustion of diesel fuel with a H/C mole ratio of approximately 1.8. The H/C ratio of methanol is 4.0 and that of ethanol is 3.0. The other major difference was that the alcohol fuels contain oxygen. Complicating the 13-mode emission calculations was the fact that the engine consumes varying relative amounts of diesel fuel and alcohol fuel, depending on load condition. The 13-mode computer program was modified to take these variations into account. In addition to f/a ratios calculated from the carbon balance of emission measurements and from measured fuel and air quantities, the f/a ratio was calculated on a "diesel fuel equivalent" basis. The "diesel fuel equivalent" was based on converting the measured portion of alcohol into a mass of diesel fuel on the basis of heating value. The diesel equivalent of the alcohol fuel was added to the measured diesel fuel, and this "total diesel fuel" was used to calculate the diesel equivalent f/a ratio. This diesel f/a equivalent ratio was used to compute the NO_x correction factor. The NO_x correction factor was computed and is given in the printout, but was not applied to the NO_x emissions measured because it is uncertain that the computed correction factor has any validity for engines not operated solely on diesel fuel. For this program,

TABLE 9. FID RELATIVE SENSITIVITIES (6)

COMPOUND	RELATIVE SENSITIVITY
Normal Paraffins	
Methane	0.97
Ethane	0.97
Propane	0.98
Butane	1.09
Pentane	1.04
Hexane	1.03
Heptane	1.00
Octane	0.97
Nonane	0.98
Aldehydes	
Butyraldehyde	0.62
Heptanoic aldehyde	0.77
Aldehydes (cont.)	
Octaldehyde	0.78
Capric aldehyde	0.80
Aromatics	
Benzene	1.12
Toluene	1.07
Ethylbenzene	1.03
para-Xylene	1.00
meta-Xylene	1.04
ortho-Xylene	1.02
1M2-Ethylbenzene	1.02
1M3-Ethylbenzene	1.01
1M4-Ethylbenzene	1.00
1,2,3-Trimethylbenzene	0.98
Aromatics (cont.)	
1,2,4-Trimethylbenzene	0.97
1,3,5-Trimethylbenzene	0.98
Isopropylbenzene	0.97
n-Propylbenzene	1.01
1M2-Isopropylbenzene	0.99
1M3-Isopropylbenzene	1.01
1M4-Isopropylbenzene	0.99
sec.-Butylbenzene	1.00
tert.-Butylbenzene	1.02
n-Butylbenzene	0.98
Unsaturates	
Acetylene	1.07
Ethylene	1.02
Hexene-1	0.99
Octene-1	1.03
Decene-1	1.01
Alcohols	
Methanol	0.23
Ethanol	0.46
n-Propanol	0.60
Isopropanol	0.53
n-Butanol	0.66
Isobutanol	0.68
sec.-Butanol	0.63
tert.-Butanol	0.74
Amyl alcohol	0.71
Methylisobutylcarbinol	0.74
Methylamyl alcohol	0.65
Hexyl alcohol	0.74
Octyl alcohol	0.85
Decyl alcohol	0.84
Acids	
Formic	0.01
Acetic	0.24
Propionic	0.40
Butyric	0.48
Hexanoic	0.63
Heptanoic	0.61
Octanoic	0.65
Esters	
Methylacetate	0.20
Ethylacetate	0.38
Isopropylacetate	0.49
sec.-Butylacetate	0.52
Isobutylacetate	0.54
n-Butylacetate	0.55
Isoamylacetate	0.62
Methylamylacetate	0.63
Ethyl-(2)-ethylhexanoate	0.72
Hexylcaproate	0.78
Celiosolve acetate	0.50
Nitrogen Compounds	
Acetonitrile	0.39
Trimethylamine	0.46
tert.-Butylamine	0.54
Diethylamine	0.61
Aniline	0.75
di-n-Butylamine	0.75
Ketones	
Acetone	0.49
Methylethylketone	0.61
Methylisobutylketone	0.71
Ethylbutylketone	0.71
Diisobutylketone	0.72
Ethylamylketone	0.80
Cyclohexanone	0.72

the diesel H/C ratio was entered as 1.85, corresponding to a hydrocarbon molecular weight (per carbon atom) of 13.8759. Additional 13-mode information regarding dual-fuel usage, the various f/a ratios, and exhaust oxygen was printed out for each of the 13 modes and will be discussed in the Results, Section VI.

As with the 13-mode procedure, certain program modifications were necessary in order to compute the 1984 Transient FTP and bus cycle emissions. The modifications concerned the computations of fuel consumption on the basis of carbon balance via HC, CO, and CO_2 emissions. Additional calculations were included to compute the percent of fuel carbon for each segment of the transient test, based on actual measured diesel and alcohol fuel usage during that segment. The computed percent fuel carbon was then used in calculating the fuel consumption reported as brake specific fuel consumption (BFSC). This fuel calculation used a fuel carbon fraction of 0.866 as a multiplier for the HC mass emission. HC mass emission was computed using an exhaust HC density of 0.5768 kg/m^3 (16.33 g/ft^3)(3) on the basis of a H/C ratio of 1.85. For comparison, the percent of fuel carbon for diesel, methanol, and ethanol are 87, 38, and 26, respectively. As with the 13-mode procedure, no NO_x correction for humidity was applied to the transient results. In the case of transient test operation, the engine intake humidity and temperature were controlled to 60 - 90 grains/lb of dry air and 68 - 86°F, so a correction factor of 1 was actually used.

Some selected individual hydrocarbons (IHC) were determined from dilute exhaust samples using a CVS. Samples were taken over seven individual modes of steady-state operation and over the cold-start and hot-start transient cycles. A portion of the dilute exhaust sample collected in a Tedlar bag was injected into a four-column gas chromatograph using a single flame ionization detector and dual sampling valves. The timed sequence selection valves allowed the baseline separation of air, methane, ethane, ethylene, acetylene, propane, propylene, benzene, and toluene.(8)

Aldehydes and ketones were determined by using the 2,4-dinitrophenylhydrazine (DNPH) method.(8) Raw exhaust samples were taken during steady-state operation; whereas dilute samples were taken from the main CVS dilution tunnel during transient testing. In both cases a heated sample line and filter were maintained at 190°C (375°F). The procedure consists of bubbling filtered exhaust gases, dilute or raw, through glass impinger traps containing a solution of DNPH and HCl kept at 0°C. The aldehydes and ketones (also known as carbonyl compounds) react with the DNPH to form their respective phenylhydrazone derivatives (precipitates). These derivatives are removed by filtration followed by pentane extractions evaporated in a vacuum oven. The remaining dried extract, which contains the phenylhydrazone derivatives, is dissolved in a specific volume of toluene with anthracene internal standard. A portion of this dissolved extract is injected into a gas chromatograph and analyzed using a flame ionization detector to separate formaldehyde, acetaldehyde, acetone, isobutyraldehyde, methylethylketone, crotonaldehyde, hexanaldehyde, and benzaldehyde.

Phenols, which differ from alcohols in having the hydroxyl group (-OH) attached directly to an aromatic ring, were measured using an ether extraction procedure detailed in Reference 8. Raw exhaust samples were taken during steady-state operation, and dilute samples were taken from the main CVS dilution tunnel during transient operation. Exhaust samples were collected in impingers containing aqueous potassium hydroxide. The contents of the impingers were acidified with sulfuric acid, then extracted with ethyl ether. This extract was injected into a gas chromatograph equipped with an FID for the determination of various phenols as follows:

"Phenol"	Molecular Weight
Phenol	94.11
Salicyaldehyde	122.13
m-Cresol	108.15
p-Cresol	108.15
2,3-xylenol	122.17
3,5-xylenol	122.17
p-ethylphenol	122.17
2-isopropylphenol	136.20
2,4,6-trimethylphenol	136.20
2,3,5-trimethylphenol	136.20
2,3,5,6-tetramethylphenol	150.22

At the start of the program, both filtered and unfiltered exhaust samples were analyzed. The unfiltered exhaust samples appeared to indicate the same trends but with lower response than obtained using a filtered sample. The unfiltered exhaust sample was dropped in favor of the filtered exhaust sample on the basis of better recovery.(8)

Unburned fuel quantities were also determined for both modal and transient operation. In most cases, unburned fuel includes aldehydes, phenols, and specific hydrocarbons along with the actual aerosols and/or gas phase evaporated fuel. Unburned fuel, for this program, meant specifically unburned alcohol. For unburned methanol, dilute or raw exhaust (depending on engine operation) was drawn through glass bubblers containing distilled water at 0°C in order to condense out and collect unburned methanol.(8) The level of methanol collected was determined by gas chromatograph using an FID. Unburned ethanol was determined by collecting a dilute exhaust gas sample in a Tedlar bag and processing a small portion of this sample through a gas chromatograph procedure described in Reference 9.

Total intensity of aroma (TIA) was quantified by using the Coordinating Research Council Diesel Odor Analytical System (DOAS). Dilute or raw sample, depending on engine operation, was drawn off through a heated sample train and into a trap containing Chromosorb 102. The trap was later eluted and injected by syringe into the DOAS instrument, which is a liquid chromatograph that separates an oxygenate fraction (liquid column oxygenates, LCO) and an aromatic fraction (liquid column aromatics, LCA). The TIA values are defined as TLA = 1 + $\log_{10}$ (LCO, μg/ℓ) or TIA = 0.4 + 0.7 $\log_{10}$ (LCA, μg/ℓ) (TIA by LCO preferred). A.D. Little, the developer of the DOAS instrument, has related this fraction to TIA sensory measurement by the A.D. Little odor panel.(10) The system was intended for raw exhaust samples from steady-state operating conditions, but for this program, dilute samples of exhaust were taken in order to determine a TIA value for transient operation. Where dilute samples were taken, the corresponding TIA values were increased proportional to the dilution ratio.

2. Particulate Emissions

Particulate emissions were determined from dilute exhaust samples utilizing various collection media and apparatus, depending on the analysis to be performed. Particulate has been defined as any material collected on a fluorocarbon-coated glass fiber filter at or below a temperature of 51.7 °C (125 °F), excluding condensed water.(5) The 125 °F temperature limit and the absence of condensed water dictates that the raw exhaust be diluted, irrespective of engine operating mode. The temperature limit generally required dilution ratios of approximately 12:1 (total mixture:raw exhaust).

Total particulate-rate samples were collected on 90 mm or 47 mm Pallflex TA60A20 fluorocarbon-coated glass fiber filter media by means of double dilution or single dilution techniques. Gravimetric weight gain, representing collected particulate, was determined to the nearest microgram after the filter temperature and humidity were stabilized. This weight gain along with CVS flow parameters and engine data were used to calculate the total particulate mass emission of the engine under test.

Smoke and total particulate are related in that the relative level of smoke opacity indicates the relative level of particulate. The absence of smoke, however, does not indicate the absence of particulate. Smoke was determined by the end-of-stack EPA-PHS smokemeter which monitored the opacity of the raw exhaust plume as it issued from the exhaust pipe. Smoke opacity was determined for the 13-mode operation, power curve operation, and for the smoke FTP.(4)

Since total particulate, by definition, includes anything collected on fluorocarbon-coated glass fiber filter media, there has always been an interest to find out what constitutes the "total particulate." The following paragraphs describe the methods and analysis used to determine some of the properties of the total particulate.

Particle size distributions were determined using a Sierra Series 220 cascade inertial impactor. Dilute exhaust particles having a variety of shapes and densities were fractionated and collected according to their aerodynamic characteristics. The aerodynamic size gives information relating to the physical size, shape and density of the particulate, indicating how the particles may behave in the environment. Pre-weighed stainless steel impactor discs were used for stage collection, and a pre-weighed fluorocarbon-coated glass fiber filter was used as a back-up filter to collect all particulate aerodynamically smaller than the lowest cut-off (0.11 microns Effective Cut-Off Diameter, or ECD). Impactor flowrate was selected to provide individual stage separation from 7.4 to 0.11 microns ECD.

Sulfate, orignating from the combustion of sulfur-containing fuel, was collected as part of the particulate matter in the form of sulfate salts or sulfuric acid aerosols. A 47 mm Fluoropore (Millipore Corp.) fluorocarbon membrane filter with 0.5 micron pore size was used to collect the sample. This total particulate sample is ammoniated to "fix" the sulfate portion of the particulate. Using the barium chloranilate (BCA) analytical method, the sulfates are leached from the filter with an isopropyl alcohol - water solution (60% IPA). This extract is injected into a high pressure liquid chromatograph (HPLC) and pumped through a column to scrub out the cations and convert the sulfate to sulfuric acid. Passage through a reactor column of barium chloranilate crystals precipitates out barium sulfate and releases the highly UV absorbing chloranilate ions. The amount of chloranilate ion released is determined by a sensitive liquid chromatograph UV detector at 310-313 nanometers. "Sulfate" should be understood to mean SO_4= as measured by the BCA method.(8)

Carbon, hydrogen, metals, and other elements that make up the total particulate are also of interest. A sample of "total particulate" was collected on 47 mm Type A (Gelman) glass fiber filter media for the purpose of determining the carbon and hydrogen weight percentages. This analysis was performed by Galbraith Laboratories using a Perkin-Elmer Model 240B automated thermal conductivity CHN analyzer. This instrument was designed for analysis of liquid samples. In order to accommodate the particulate sample on a filter, the filter must be folded or rolled over itself. As the temperature is increased, the glass fiber media collapses on itself, sometimes locking in some of the particulate. For this reason significant inaccuracies can occur. One of the ways to improve the accuracy was to collect relatively high particulate loadings. This was possible for steady-state operation but difficult for transient testing.

A sample of total particulate matter was also collected on a 47 mm Fluoropore filter for the determination of trace elements such as calcium, aluminum, phosphorus, and sulfur by X-ray fluorescence. This analysis was conducted at the EPA, ORD laboratories in Research Triangle Park, N.C. using a Siemens NRS-3 X-ray fluorescence spectrometer.

3. Soluble Organics

Carbon has long been recognized as an excellent adsorbing medium for hydrocarbon aerosols. Similarly, it has been recognized that carbonaceous particulate could readily adsorb hydrocarbons present in the exhaust. In order to determine to what extent total particulate contains these various hydrocarbons, particulate filter samples were washed with an organic solvent, methylene chloride. The dissolved portion of the "total particulate" carried off with the methylene chloride solvent has been referred to as the "soluble organic fraction" (SOF). As with total particulate the SOF may be composed of anything carried over by the extraction process, so its composition is also of interest. Generally the SOF contains numerous organic compounds, many of which are difficult to isolate and to quantify. Some SOF has been shown to be mutagenic using the Ames test.

Relatively large amounts of soluble organic fraction (some 300 mg) are generally needed for elemental characterization and Ames testing. Large 500 x 500 mm (20x20 in.) Pallflex filters were used to collect correspondingly large amounts of total particulate for extraction. As mentioned earlier, both CVS units used in this program can collect three 20x20 particulate samples simultaneously. These filters are weighed to determine the particulate loading, then stored in glassine bags within a brown paper envelope. Several of these envelopes are grouped and sealed in a Tedlar bag purged with nitrogen. The Tedlar bags are then stored in a freezer until needed for extraction. These steps generally take place within a few hours of sample collection, and are carried out under yellow light (ultraviolet light filtered out using Kodak "yellow chrome II" film).

When specific total particulate samples are selected for extractions, the corresponding filters are pulled from freezer storage and extracted in soxhlet extractors as shown in Figure 12. After adequate cycling time, the solvent (methylene chloride) containing the extractables is filtered, then evaporated to "dryness" in a preweighed vial using blown-in nitrogen. The weight of the "dried" extract is determined, and the SOF percent of total particulate calculated. "Dried" refers to the complete removal of the solvent. The vial contents are either distributed for analysis or stored in the freezer for subsequent analysis or shipment. As with filter handling, all extraction steps were carried out under yellow light.

Carbon, hydrogen, sulfur, and nitrogen were determined for the SOF. Carbon and hydrogen content of the "dried" extract was determined by Galbraith Laboratories using a Perkin-Elmer Model 240B automated thermal conductivity CHN analyzer. A portion of the extract was submitted to SwRI's Mobile Energy Division for nitrogen analysis by chemiluminescence and sulfur analysis by X-ray fluorescence.

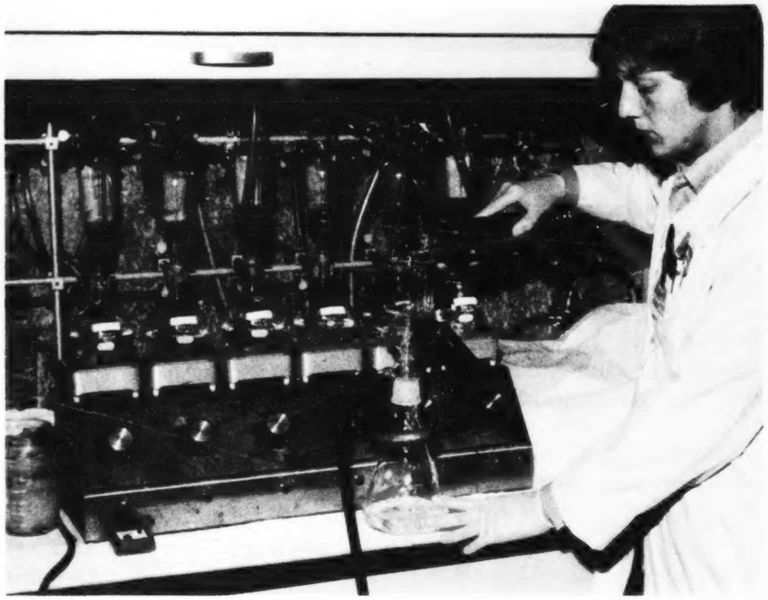

Figure 12. Soxhlet Extraction of particulate for soluble organic fraction

The boiling range of the SOF was determined by SwRI's Mobile Energy Division using a high-temperature variation of ASTM-D2887-73. Approximately 50 mg of the SOF was dissolved in solvent and an internal standard (C_9 to C_{11} compounds) was added. This sample was then submitted for instrumental analysis of boiling point distribution.

Another portion of the SOF sample was submitted for fractional separation. The method involves separation of the extractables into a series of fractions of increasing polarity. A high performance liquid chromatographic procedure which utilizes a variable solvent program is used to elute increasingly polar compounds. BaP, 9-flurorenone and acridine standards are injected to indicate the types of compounds eluted in each region of the chromatogram.(11)

BaP is considered to be an elementary indicator of the relative PNA content of the SOF. The analytical method used for the determination of BaP is described in Reference 12. The procedure is based on high-performance liquid chromatography to separate BaP from other organic solubles in particulate matter, and it incorporates fluroescence detection to measure BaP. The instrument used was a Perkin-Elmer 3B liquid chromatograph equipped with a MPF-44 fluorescence spectrophotometer. Excitation was at a wavelength of 383 nm, and emission was read at 430 nm.

As mentioned earlier, there is concern about the potential health effects impact that diesel exhaust may have. The emphasis of this concern has been placed on the SOF which was submitted for Ames testing.

The Ames test, as employed in this program, refers to a bacterial mutagenesis plate assay with Salmonella typhimurium according to the method of Ames.(13) This bioassay determines the ability of chemical compounds or mixtures to cause mutation of DNA in the bacteria, positive results occurring when histidine-dependent strains of bacteria revert (or are mutated) genetically to forms which can synthesize histidine on their own. Samples of SOF were shipped under dry ice to EG&G for Ames test response. Details of this procedure can be found in References 13 and 14.

IV. RESULTS

This section describes the results obtained from numerous emission measurements and sample analysis conducted on both the Volvo TD-100C diesel engine and the Volvo TD-100A dual-fuel engine. It is divided into three parts. The first part gives preliminary emission test results used to decide on engine timing and cold start-up procedures, along with general test notes which describe some of the pertinent details and the chronology of the accumulated test results. The next two parts detail the accumulated gaseous and particulate data, respectively. Overall emission trends, comparisons of data, and general remarks are given along with the results.

A. Preliminary Results and General Test Notes

The dual-fuel engine was installed in the SwRI transient test facility which includes a 28-170 m^3/minute (1000-6000SCFM) double-dilution CVS and a transient-capable dynamometer and control system. All transient work and some selected steady-state work were conducted in this test facility. This is the same facility used for the EPA "Baseline" Contract 68-03-2603, "Emissions from Heavy-Duty Gasoline and Diesel Engines Used in Vehicles Above 8,500 Pounds Gross Vehicle Weight." Extensive steady-state characterization was conducted in SwRI's steady-state test facility which utilizes a 28 to 340 m^3/minute (1,000 to 12,000 SCFM) single dilution CVS.

Following initial setup and operational checkout of the engine, Mr. Bert-Inge Bertilsson (of Volvo) adjusted the linkage connecting the rack of the diesel pump to the alcohol pump, changing the low flow stop setting of the diesel pump on the basis of HC and smoke emissions at 1400 rpm motoring and full load conditions. Static engine timing of the alcohol fuel injection pump was not changed from the "as-received" setting of 24°BTDC. Using the rack stop adjustment inside the alcohol pump, the maximum power was set to 186.5 kW (250 hp) at 2200 rpm, with methyl alcohol as the main fuel and using 13-mode intake and exhaust restrictions. Intake restriction and exhaust backpressure used in this emission characterization program are listed below. The 13-mode restrictions were based on certification data for a diesel TD-100C engine, and transient restrictions were based on "typical" limits for intake and exhaust restrictions.

	Restrictions at Maximum Power	
	Intake, mm H_2O (in H_2O)	Exhaust, mm Hg (in Hg)
13-Mode	660 (26.0)	91 (3.6)
Transient	300 (11.8)	74 (2.9)

Preliminary test results were requested by the Project Officer in order to choose between a static timing of 24° or 19°BTDC for alcohol injection timing. Information was also requested in order to establish a cold-start procedure which would be suitable for use with the transient cycle FTP. Following several delays related to dynamometer control, torque transducer, and driveline vibration (near idle speed of 500 rpm) problems; the engine was mapped under transient conditions according to the 1984 FTP, and a transient cycle control tape was generated.

The same engine control tape for the transient cycle, based on the 24°BTDC map, was used for both 24°BTDC and 19°BTDC transient tests. Results from these preliminary transient tests are given in Table 10.

The 13-mode results were processed per the 1979 procedure, which utilized the carbon balance and measured fuel to determine the regulated emission rates. Methanol fuel consumption was converted to "equivalent diesel fuel" on the basis of heating value. This "equivalent diesel fuel" was added to the measured diesel fuel used, and the emissions data processed through the 13-mode computer program normally used for diesel engines. Humidity corrections for NO_x were applied to the preliminary data. Thirteen-mode HC and NO_x emissions were about as expected, but CO levels were significantly higher than those obtained by Volvo. Several checks, including CO instrument calibration and methanol interference, were made. An additional ice trap was used to assure a dry CO measurement. No cause for the relatively high CO was found. "HC" represents total hydrocarbons indicated using a Beckman 402 heated flame ionization detector (HFID).

The transient results were quite repeatable. Run 3 of the transient test cycle was run with the cycle control tape started 25 seconds after the engine was started. The 25 second delay was to allow time for the preheat cycle to expire and for the alcohol fuel pump to be "ON" during the first active engine demand which occurs at 23 seconds from the start of the cold-start transient cycle. The engine, as received, had a shorter preheat cycle after start-up than anticipated. The preheat cycle expired automatically between 30 and 40 seconds. No significant difference between the third cold-start and the other two cold-starts at 24°BTDC can be attributed to the 25 second delay of the cycle.

The timing of the alcohol injection pump was changed from the as-received 24°BTDC to 19°BTDC. Both steady-state and transient test data showed definite changes due to 5° timing retardation of the alcohol injection pump. The most notable and expected results were a reduction in NO_x emissions and an increase in fuel consumption. In addition, the particulate emissions, which were already relatively low at 24°BTDC, decreased even further with retarded timing of alcohol injection. It was noted that the cold-start, with either timing, had slightly lower particulate emissions than the hot-start transient. These relatively low particulate rates were determined, as usual, from collection by two 90 mm filters in series. Filter efficiency averaged about 83 percent, which is lower than for most diesel-only engines tested.(15) Based on these results,

TABLE 10. PRELIMINARY TEST RESULTS FROM VOLVO TD-100A DUAL FUEL ENGINE

	24°BTDC			19°BTDC		
	Cold Trans	Hot Trans	13-mode[b]	Cold Trans	Hot Trans	13-mode[b]
Run 1						
HC, g/bhp-hr[d]	1.45	1.34	1.239	1.43	1.34	1.123
CO, g/bhp-hr	7.08	6.19	7.289	8.37	7.79	7.559
CO_2, g/bhp-hr	659.	629.	--	707.	684.	--
NO_x, g/bhp-hr	5.73	5.70	5.553	4.92	4.88	4.143
Part., g/bhp-hr	0.27	0.30	--	0.22	0.24	--
BSFC, lb/bhp-hr[c]	0.886	0.842		0.980	0.930	
Cycle Power, hp-hr	15.52	15.43		15.37	15.62	
Run 2						
HC, g/bhp-hr[d]	1.62	1.33	1.273	1.43	1.38	1.065
CO, g/bhp-hr	7.69	7.09	7.434	8.67	7.86	7.484
CO_2, g/bhp-hr	647.	627.	--	705.	690.	--
NO_x, g/bhp-hr	5.83	5.72	5.487	4.84	4.75	4.156
Part., g/bhp-hr	0.26	0.28	--	0.22	0.25	--
BSFC, lb/bhp-hr	0.905	0.840		0.960	0.934	
Cycle Power, hp-hr	15.25	15.37		15.42	15.50	
Run 3[a]						
HC, g/bhp-hr[d]	1.38	1.32				
CO, g/bhp-hr	7.47	6.48				
CO_2, g/bhp-hr	646.	619.				
NO_x, g/bhp-hr	5.64	5.67				
Part., g/bhp-hr	0.28	0.32				
BSFC, lb/bhp-hr	0.873	0.835				
Cycle Power, hp-hr	15.16	14.96				

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[a] Run 3 was to determine if there was a significant difference in cold-start procedure, namely, the cycle control tape was delayed by 25 sec. from engine start-up

[b] 13-mode results are reported from calculations based on equivalent diesel fuel- NO_x correction applied

[c] BSFC was calculated from carbon balance - utilizing a calculated percent carbon in the dual fuel

[d] HC as indicated by Beckman 402 HFID

it was decided by the Project Officer that emissions characterization whould be pursued with static timing of the alcohol injection at 19° BTDC due to lower emissions of NO_x and particulate.

As mentioned above, the second preheat cycle was running approximately 30 to 40 seconds. Additional checks into the circuitry were made, and it was discovered that the engine cooling water temperature sensor was defective. An additional cold-start procedure was run, manually holding the alcohol pump to "OFF" for 50 seconds. The result was that the engine could not follow the first active portion of the transient cycle, as anticipated, and also that it produced slightly higher HC emissions as noted from continuous HC traces. Since after only 25 seconds of idle from cold start-up the alcohol was undergoing combustion, it was decided that the preheat would be terminated manually 23 to 25 seconds after engine and test cycle start. Details of the cold-start sequence were described in Section III.B., page 14.

Having completed the preliminary tests, the dual-fuel engine was mapped in the "methanol" test configuration with the alcohol pump set to 19°BTDC. Methanol configuration refers to the dual-fuel diesel engine adjusted to operate on methanol (main fuel), with pilot injection of diesel fuel in varying proportions depending on speed and load. Both a 1984 transient FTP control tape and a bus cycle control tape were generated.

Chronologically, the methanol configuration was run first. The engine operated well, and appeared to follow the active portions of the transient cycle. Several initial tests were repeated for various reasons which included incomplete data recovery, or void sample collection along with some engine-related solenoid actuation problems. Optimization of the dynamometer controls continued in an attempt to stay within statistical requirements. As testing progressed, it appeared that engine-driveline vibration began to interfere with torque measurement at idle. This caused the rack position to vary slightly, which broke the electrical contact activating the diesel pump solenoid, switching it from "high" flow to "low" flow. This situation appeared to have no effect on steady-state engine operation, but it was uncertain what effect it might have on transient operation and emissions. On the basis of information received at the time, switching of the diesel pump solenoid was of little or no consequence and testing continued. The driveline vibration resonance occurred around 800 rpm, but the fringe of the vibration began around the 500 rpm engine idle speed. Dynamometer control and statistical results were somewhat uncertain from day to day because of the engine idle, dynamometer control, and dynamometer driveline vibration interaction.

Following completion of transient testing in the methanol configuration, an oxidation catalyst was installed in the exhaust system about 0.6 m (2 ft) from the turbocharger outlet. No adjustment to the alcohol injection pump was made. This test configuration was referred to as the "methanol-catalyst" configuration. Several transient tests were conducted in this configuration while striving to obtain the best statistical results with closed rack during idle. In the meantime, Volvo requested that the rack be fully closed during idle to insure electrical contact for the diesel solenoid operation. In order to assure throttle closure, a large negative torque command was issued during idle commands. With the throttle fully closed, the engine may have been motored more than for previous runs. Results from these runs did not appear to be representative, and were not used. Other methods of dynamometer control were pursued.

As testing of the methanol-catalyst configuration was being completed, a conference was held with Mr. Ernst Holmér of Volvo. It was decided that the dual-fuel engine should be operated with the diesel pump set to "low" flow, after cold start-up using "high" flow. This meant that the problem with intermittent solenoid actuation during idling periods could be bypassed. He also requested that a backpressure device be used with future catalyst testing in order to reduce warm-up time of both the engine and the catalyst. Additional transient tests were requested to verify the influence of the "high" flow diesel actuation and the influence of the actual start-up "puff" on particulate measurements.

The catalyst was removed from the dual-fuel engine exhaust system and the alcohol fuel was changed from methanol to ethanol. Due to the significantly greater heating value of ethanol, the alcohol injection pump was adjusted to account for the difference. The injection pump was adjusted to obtain 186.5 kW at 2200 rpm. This configuration was referred to as the "ethanol" test configuration. Following the completion of 13-mode FTP gaseous emission testing, the additional hot-start transient runs requested by Volvo were conducted. To insure positive rack closure, a large negative torque command was issued during idle commands. The first test was conducted with particulate sampling as normal, and with the diesel fuel flow switched to "high" flow at closed rack conditions. The second hot-start transient used the identical command program, but the 90 mm particulate sample activation was delayed by 10 seconds in order to miss the engine start-up "puff." The third hot-start transient was conducted with particulate sampling as normal, but with the diesel fuel flow switched to "low" flow throughout the test. Detailed results of these three runs are given in Appendix E as Tables E-2, E-3, and E-4. Essentially no difference between the three tests could be attributed to the variables intentionally changed. Volvo preferred that the "low" flow setting be used on subsequent transient tests, including cold-starts. Following these special tests, normal command tapes were once again used.

Initial cold-start transient tests, run with the diesel fuel set to "low." caused the engine to false start. It was agreed that the "high" diesel flow would be used for the first 23 seconds, and that the pump would then be switched to "low" flow. Vibration during idle conditions continued to cause problems with meeting statistical requirements, but were not thought to have any substantial effect on the emissions. While testing was being completed for the ethanol configuration, a backpressure device to be used with the catalyst was received.

Following completion of the ethanol configuration, the catalyst and the backpressure device were installed on the dual-fuel engine. This configuration was referred to as the "ethanol-catalyst-backpressure" configuration. The backpressure device was activated by closed rack conditions such as motoring or idle. The device is described in Section III. B. Diesel fuel consumption had to be increased by means of adjustment to the diesel pump and the linkage connecting the diesel and alcohol injection pumps in order to maintain 500 rpm idle speed. Driveline vibration still continued to be an annoyance, so in order to change the resonant frequency, a stiffer torque meter was installed (100K in lb).

Following the completion of transient tests in the ethanol-catalyst-backpressure configuration, the alcohol fuel was changed from ethanol to methanol. A few transient tests were conducted in this "methanol-catalyst-backpressure" configuration in order to see what effect the backpressure device might have. No 13-mode FTP emission tests were conducted in this configuration, but idle emissions were measured with the device engaged.

The intent of the backpressure device was to increase and help maintain catalyst temperature, thereby decreasing the catalyst warm-up time during the cold-start. Figure 13 shows catalyst inlet and outlet temperature profiles during cold- and hot-start transient operation with and without the backpressure device. The backpressure device caused the catalyst inlet temperature profile to appear more erratic and to attain higher peak values. The catalyst inlet gas temperature profile from both the cold-start and the hot-start transient overlapped after 500 seconds with the backpressure device. This overlap occurred after only 375 seconds without the backpressure device. Similarly, the catalyst outlet temperature overlapped earlier (490 seconds) without the backpressure device than with the device (650 seconds). Without the backpressure device, the catalyst outlet temperature reached 200°C after 415 seconds, whereas it took 450 seconds with the device. Both catalyst inlet and outlet temperatures were increased after 900 seconds of the transient cycle with the use of the backpressure device. Overall, the backpressure device appears to have relatively minor influence on the warm-up profile of the catalyst.

Following completion of the tests with methanol-catalyst-backpressure, the catalyst was removed and the backpressure device disabled. Some additional runs were made in the methanol and ethanol fuel configurations in order to repeat part of the unregulated sample collection. Upon completion of these runs, the engine was moved to the steady-state, single-dilution CVS test facility to undergo extended steady-state emissions testing.

The engine was adjusted to the methanol configuration. Aldehydes were taken over 11 modes of the 13-mode procedure, including all 10 of the intermediate and rated speed power modes along with one idle mode. Samples for particulates, individual hydrocarbons, unburned methanol, and odor index were taken for seven modes of operation (they included

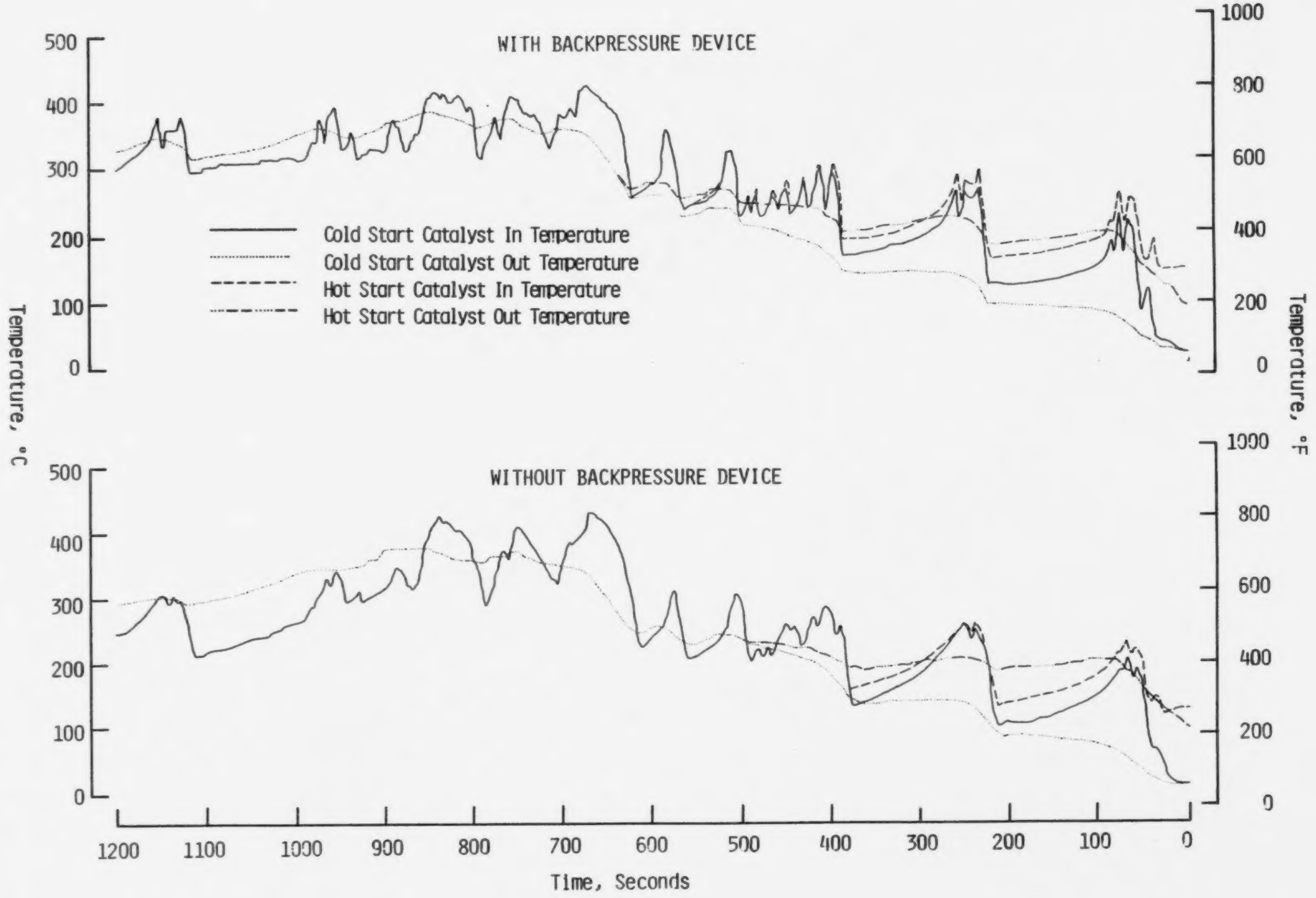

Figure 13. Catalyst warm-up profiles with and without a backpressure device during transient FTP operation

the 2, 50, and 100 percent load conditions at both rated and intermediate speeds, plus an idle mode).

Similar samples were collected with the dual-fuel engine in the methanol-catalyst configuration. In order to collect sufficient particulate sample at idle, as well as for other modes, sample times of up to one hour were required. Following light engine load conditions, the engine was operated at high power to burn off any raw fuel or oils which might have accumulated in the exhaust system. An additional idle mode was run in the methanol-catalyst-backpressure configuration in order to determine what effect the backpressure device had on emissions.

In the course of the program, it was decided not to conduct steady-state testing of the dual-fuel engine in either the ethanol or the ethanol-catalyst-backpressure configurations. Since no data had been collected using ethanol and 30 percent water by mass, it was decided that some steady-state characterization should be conducted. Changing from the methanol to the "ethanol+water" configuration required only minimal adjustments to the alcohol injection pump since both "fuels" have similar heating values on a volume basis.

Aldehydes, individual hydrocarbons, unburned ethanol and particulate were measured for seven modes of operation. Test modes included the 2, 50, and 100 percent load conditions at both rated and intermediate speeds. Idle data from the dual-fuel engine in the methanol fuel configuration were used for the ethanol+water configuration, since no fuel other than diesel was consumed at idle. Fuel measurements at the 1400 rpm/2 percent load condition also indicated that only diesel fuel was consumed at this condition, but it was nevertheless repeated because it was near the point at which the alcohol fuel was added. There were significant similarities in regulated as well as unregulated emissions between the ethanol+water configuration and the methanol configuration. Due to these similarities, transient testing in the ethanol+water configuration was not conducted in favor of obtaining transient diesel engine data.

While the steady-states were underway, an EPA correlation program had been completed in the transient facility. The diesel Volvo TD-100C was installed in the transient test facility. Once the transient FTP testing was completed, the engine remained in the facility for steady-state characterization similar to that conducted on the dual-fuel engine. Upon completion of sample collection, the test phase of the program ended.

B. Gaseous Emissions

The term "gaseous emissions" usually refers to HC, CO, and NO_x, which are currently regulated emissions. This section presents the results of emission measurements which include not only these regulated gaseous emissions, but also individual hydrocarbons, unburned alcohols, aldehydes, and phenols. These additional species are generally included in a qualitative way as part of the "total hydrocarbon." Odor intensity, which has been shown to correlate with the presence of these and other gas phase emissions, is also presented.

1. HC, CO, and NO_x

These regulated pollutants were measured over the 1979 FTP as well as the 1984 Transient FTP. In 1984, the transient test procedure will be optional in lieu of the 13-mode test procedure. In 1985, the transient test procedure will become mandatory, and in 1986 the transient test procedure will include particulate measurement and regulation. For perspective, some of the proposed standards, beyond 1979, are listed in Table 11.

TABLE 11. HEAVY-DUTY DIESEL REGULATED EMISSION LIMITS, 1979-1986

Model Year	FTP	Regulated Emissions (g/hp-hr) HC	CO	NO_x	Particulate
1979	13-mode	1.5	25.	10.0	None[a]
	13-mode (opt.)	--	25.	5.0	None[a]
1984	13-mode[b]	0.5	15.5	9.0	None[a]
	Transient[b]	1.3	15.5	10.7	None[a]
1985	Transient	1.3	15.5	10.7	None[a]
1986	Transient	1.3	15.5	4.0	.25

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[a] Federal Smoke Regulations
[b] Manufacturer may certify by either procedure

a. 13-mode FTP

Two 1979 13-mode Federal Test Procedures for gaseous emissions were conducted in six test configurations. The six included the Volvo TD-100C diesel engine as received, and the Volvo TD-100A dual-fuel engine in the methanol, methanol-catalyst, ethanol, ethanol-catalyst-backpressure and ethanol+water test configurations. A summary of average 13-mode gaseous emissions from the six test configurations is given in Table 12. Copies of the individual 13-mode computer printouts are given in Appendix A, providing detailed information on a modal basis.

The diesel engine had slightly lower HC and substantially lower CO than did the alcohol-fueled configurations without catalyst, all of which had very similar HC and CO emissions. As expected, the catalyst was most effective with methanol, reducing the HC and CO by 90 percent; whereas with ethanol the catalyst reduced HC and CO levels by about 65 percent. Although CO levels from the alcohol configurations with catalyst were three times those of the diesel engine, they were still below the 1984 limit. It should be noted that the HC values reported here are based on measurements by HFID. The FID response is very low for unburned alcohols and some other species of unregulated emissions.

The diesel configuration had the highest emission of NO_x. The NO_x emission rates shown in Table 12 are without the usual correction for

TABLE 12. GASEOUS EMISSION SUMMARY FROM 13-MODE OPERATION OF THE VOLVO TEST ENGINES

	13-Mode			
	Emissions[a], g/kw-hr (g/hp-hr)			BSFC[g] kg/kw-hr (lb/hp-hr)
Test Configuration	HC	CO	NO_x	
Diesel	1.05 (0.78)	3.18 (2.37)	11.88[e] (8.86)	0.262 (0.431)
Methanol	1.45[f] (1.08)	0.55 (7.12)	5.26 (3.92)	0.486 (0.799)
Methanol -Catalyst[c]	0.16[f] (0.12)	0.83 (0.62)	6.79 (5.06	0.482 (0.792)
Ethanol	1.65[f] (1.23)	10.52 (7.84)	6.85 (5.11)	0.395 (0.650)
Ethanol -Cat.-Bp.[d]	0.60[f] (0.45)	3.10 (2.31)	7.98 (5.95)	0.400 (0.657)
Ethanol + Water	1.89[f] (1.41)	9.99 (7.45)	4.46 (3.32)	0.495 (0.814)

---

[a] Computed on the basis of molecular weight of the fuel or fuel combination used

[b] NO_x correction factor for intake humidity was computed but not applied

[c] Without backpressure device

[d] With backpressure (Bp.) device - engaged only at idle

[e] NO_x value is reduced to 10.89 g/kW-hr (8.12 g/hp-hr) when the intake humidity correction for NO_x is applied

[f] HC values reported here are based on measurements by HFID. FID response is very low for unburned alcohols and some other species of unregulated emissions

[g] BSFC is in terms of dual fuel rather than diesel fuel where applicable

intake air humidity. The correction was omitted to facilitate comparisons between the diesel fuel configuration and the alcohol configurations. NO_x correction for intake air humidity was not applied to any of the alcohol configuration results, because of the uncertainties in computation of such a correction factor where fuels containing water and oxygen are involved. Copies of the computer printouts, with the humidity correction applied to the diesel engine's emissions, are given in Appendix A, Tables A-1 and A-2.

Considering only the alcohol-fueled configurations without catalyst, ethanol had the highest NO_x emissions, followed by methanol, then ethanol+water. It appears that the catalyst was associated with increased NO_x emissions, although emission levels before and after the catalyst showed only minor increases in NO_x. The ethanol-catalyst configuration was run using a backpressure device active during idle. NO_x emissions at idle increased by about 30 percent with the device engaged. The backpressure device was not used for the methanol-catalyst configuration during the 13-mode FTP.

Brake specific fuel consumptions for the various configurations are also given in Table 12. As discussed in Section III.D., fuel consumption was computed on the basis of the measured mass of combined fuel. The relatively high BSFC values for alcohols can be ranked according to their heating value on a mass basis. The amounts of diesel fuel and alcohol fuel usage were dependent on the load condition. Figure 14 illustrates graphically the variable fueling schedule used for the methanol, ethanol, and ethanol+water configurations.

The amount of diesel fuel injected is constant at each engine speed, whereas the alcohol portion changes with load. The relative amount of alcohol consumed during a given mode is proportional to the heating value of the alcohol used. Diesel fuel consumed by the Volvo diesel TD-100C is also shown in order to indicate the amount of diesel fuel replaced by alcohol. Variation in alcohol consumption during the 2200 rpm/2 percent load condition (mode 12) was due to difficulty in measuring low fuel flow with a relatively large meter. In addition, it appears that "neat" ethanol can be conserved by consuming ethanol mixed with water. This trend may be due to ignition timing effects, or improved turbocharger performance which could improve engine efficiency. The ethanol+water was measured as a mixture, and the water content was calculated assuming 30 percent by mass. The measured density of the ethanol+water mixture indicated that the actual water content was 29 percent by mass.

On a 13-mode composite basis, diesel fuel consumption was reduced from 0.28 kg/min with the diesel engine, to 0.097 kg/min with the dual-fuel engine. This represents a 65 percent substitution of alcohol for diesel fuel over the 13-mode composite. Details of 13-mode fuel consumption may be found in the reduced copies of the computer printouts which are given in Appendix A. Fuel molecular weight was also computed on a modal basis, and is given in these printouts.

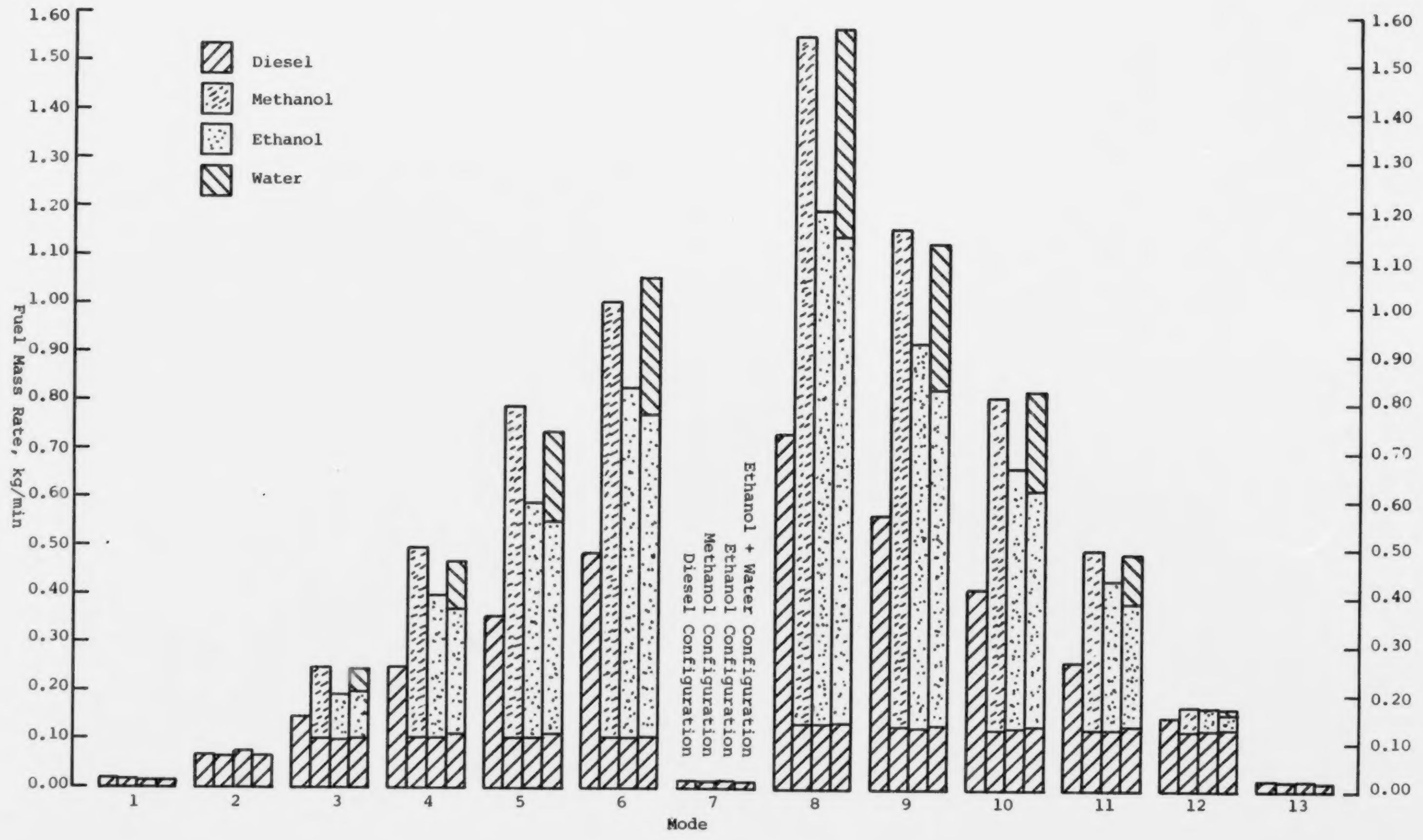

Figure 14. Illustration of diesel pilot and alcohol fuel injection schedules measured during 13-mode FTP

b. Transient FTP

The transient test procedure was run with the engine on the transient-controlled stationary dynamometer, the total exhaust transferred to a double-dilution CVS, and primary dilution at a nominal flow rate of 2000 CFM. Transient cycle particulate emissions were determined via a 4 CFM (total flow) secondary dilution system using 90 mm Pallflex filters. Transient cycle gaseous emissions of CO and CO_2 were determined from proportional bag samples of the primary dilution flow. Integrations of individual analyzer outputs were used to determine emissions of HC and NO_x. The transient test consists of a cold-start cycle, 20 minute soak, then a hot-start cycle. The results from these cycles are combined into a composite transient result as described in Section III.C.

A summary of the average gaseous emission results obtained from transient testing is given in Table 13. The results from the cold-start and the hot-start represent averages of several individual tests. Reduced copies of computer printouts for these individual tests are given in Appendices B, C, D, E, and F; for diesel, methanol, methanol-catalyst (including methanol-catalyst-backpressure), ethanol, and ethanol-catalyst-backpressure configurations, respectively. Appendix Tables B-1, C-1, D-1, E-1, and F-1 give additional qualifying information for individual tests, and indicate whether or not the results were included in the average values in Table 13. Transient FTP composite values given in Table 13 were computed using the average cold and hot FTP values. Particulate emission rates are also given in Table 13, but discussion of these data will be reserved for the particulate section of the report.

The HC values given in this report represent the total hydrocarbons indicated by the Beckman Model 402 HFID. It has been noted that the FID has low response to some species of oxygenated hydrocarbons, such as alcohols and aldehydes. In addition, NO_x values reported for transient operation in this section were not corrected for engine intake air humidity due to the use of a humidity- and temperature-controlled intake air system.

Both the diesel engine and the dual-fuel engine appear to be slightly cold-start sensitive in regard to HC, CO, and NO_x emissions. All these gaseous emissions and the calculated BSFC were higher for the cold-start than for the hot-start transient test. Comparing transient composite results, emissions of both HC and CO were higher with the alcohol-fueled engine configuration than for the diesel configuration. HC and CO were highest with ethanol, although CO levels were still below the proposed 1984 standard. NO_x emissions were similar for both alcohols, and were relatively low compared to the diesel configuration. The oxidation catalyst with the backpressure device appears to have reduced emission of HC and CO as expected, and to have increased NO_x somewhat. From steady-state data, some increase in NO_x occurred during idle when the backpressure device was operating. The catalyst appeared to be more active in the methanol configuration.

TABLE 13. REGULATED EMISSIONS[e] SUMMARY FROM TRANSIENT FTP OPERATION OF THE VOLVO TEST ENGINES

Test Configuration	Cycle Type	Regulated Emissions[e], g/kw-hr, (g/hp-hr)				Cycle BSFC[a] kg/kw-hr (lb/hp-hr)	Cycle Work kw-hr (hp-hr)
		HC[d]	CO	NO_x[b]	Part.		
Diesel	Cold Start	1.58 (1.18)	4.84 (3.61)	11.78 (8.79)	0.80 (0.60)	0.306 (0.502)	10.29 (13.79)
	Hot Start	1.08 (0.80)	3.90 (2.91)	11.09 (8.27)	0.68 (0.51)	0.284 (0.468)	10.54 (14.13)
	Transient Composite	1.15 (0.85)	4.04 (3.01)	11.19 (8.34)	0.70 (0.52)	0.288 (0.473)	10.50 (14.08)
Methanol	Cold Start	1.98 (1.48)	11.85 (8.84)	7.55 (5.63)	0.36 (0.37)	0.561 (0.922)	11.27 (15.10)
	Hot Start	1.94 (1.45)	10.03 (7.48)	7.27 (5.42)	0.40 (0.30)	0.526 (0.873)	11.27 (15.11)
	Transient Composite	1.95 (1.45)	10.29 (7.67)	7.31 (5.45)	0.39 (0.30)	0.531 (0.873)	11.27 (15.11)
Methanol -Catalyst	Cold Start	0.36 (0.27)	5.54 (4.13)	7.44 (5.55)	0.26 (0.19)	0.538 (0.885)	11.13 (14.92)
	Hot Start	0.13 (0.10)	3.29 (2.45)	7.38 (5.50)	0.34 (0.25)	0.515 (0.946)	11.19 (15.01)
	Transient Composite	0.16 (0.12)	3.61 (2.69)	7.39 (5.51)	0.33 (0.24)	0.518 (0.852)	11.19 (15.00)
Methanol -Cat. Bp.[c]	Cold Start	0.62 (0.46)	6.09 (4.54)	8.90 (6.64)	0.28 (0.21)	0.622 (1.022)	10.62 (14.24)
	Hot Start	0.21 (0.16)	3.49 (2.60)	8.31 (6.20)	0.42 (0.31)	0.567 (0.933)	11.37 (15.24)
	Transient Composite	0.27 (0.20)	3.86 (2.88)	8.39 (6.26)	0.40 (0.30)	0.575 (0.946)	11.26 (15.10)
Ethanol	Cold Start	2.28 (1.70)	13.29 (9.91)	7.48 (5.58)	0.34 (0.25)	0.451 (0.742)	11.45 (15.36)
	Hot Start	2.27 (1.69)	12.82 (9.56)	7.36 (5.49)	0.35 (0.26)	0.432 (0.711)	11.38 (15.26)
	Transient Composite	2.27 (1.69)	12.89 (9.61)	7.38 (5.50)	0.35 (0.26)	0.435 (0.715)	11.39 (15.27)
Ethanol	Cold Start	0.79 (0.59)	5.65 (4.21)	8.77 (6.54)	0.34 (0.25)	0.465 (0.764)	10.95 (14.67)
	Hot Start	0.60 (0.45)	4.01 (2.99)	8.60 (6.41)	0.39 (0.29)	0.445 0.732)	11.01 (14.76)
	Transient Composite	0.63 (0.47)	4.24 (3.16)	8.62 (6.43)	0.38 (0.28)	0.448 (0.737)	11.00 (14.75)

---

[a] BSFC is in terms of dual fuel rather than diesel fuel where applicable. Approximately 80%, by mass, of the fuel consumed during a transient cycle was alcohol. Heating values are: diesel at 42.90 MJ/kg (18,400 BTU/lb), methanol at 19.88 MJ/kg (8,550 BTU/lb), and ethanol at 27.01 MJ/kg (11,600 BTU/lb)

[b] NO_x values presented here are based on continuous measurement by chemiluminescence. NO_x values for some runs were also computed from bag sample measurement by CL and are reported in the corresponding Appendix. Intake humidity was controlled - NO_x correction of 1.00 used in all cases for transient NO_x.

[c] Bp. stands for backpressure device

[d] HC values reported here are based on indication by HFID (Beckman 402). FID response has been reported to be very low for unburned alcohols and some other species

[e] Regulated emissions include HC, CO, NO_x, and particulate as proposed for 1986 Transient FTP

c. Bus Cycle

Emission levels were also determined for the transient bus cycle. The bus cycle was run 20 minutes after completing the hot-start transient cycle, or 20 minutes after completing another hot-start bus cycle. A summary of the average gaseous emissions results is given in Table 14. Reduced copies of these bus cycle tests are presented in Appendices which correspond to the fuel configurations listed for transient FTP results. Generally, all the HC, CO, and NO_x emissions were higher for the bus cycle than for the transient FTP. The most significant difference between the two cycles appears to be the increase in CO emissions from the alcohol-fueled configurations. A significant increase in CO was not observed in the diesel configuration, although diesel HC and NO_x were somewhat higher.

The BSFC's were higher for the bus cycle than for corresponding transient FTP's. Fuel consumption has been reported in terms of "dual" fuel which has a significantly lower heating value per unit mass than does No. 2 diesel fuel. The BSFC data given in Tables 13 and 14 are computed on the basis of carbon balance. They are somewhat dependent on measured alcohol and diesel fuel consumed during the test, in that a "percent fuel carbon" is calculated from the measurements and used in the carbon balance computations for fuel consumption.

The percent of fuel carbon for No. 2 diesel is usually around 87 percent. Some of the calculated "percent of fuel carbon" values, by fuel and by bag of the transient test, are given in Table 15. The percent fuel carbon values for methanol and ethanol are 38 and 52 weight percent, respectively. In general, calculated percent of fuel carbon ranged from a low of 46 to a high of 66, depending on the type of alcohol used, the cycle activity and loading, and the amount of diesel fuel used. Higher percentages of alcohol by weight were used in the methanol configuration, due to the lower heating value of methanol as compared to ethanol.

Overall, the results from the transient test agree fairly well with those of the 13-mode test procedure. HC emissions were only slightly higher from the transient FTP. Thirteen-mode CO emissions were higher for the transient procedure, especially with methanol-catalyst-backpressure configuration. The diesel configuration had higher NO_x for the 13-mode than for the transient FTP, but dual-fuel engine configurations had higher NO_x for the transient FTP than for the 13-mode. The NO_x reduction using alcohols may be cycle-sensitive, due to NO_x reduction during the high-power steady-state modes. BSFC was consistently higher on the transient procedure, for reasons already explained.

2. Selected Individual Hydrocarbons

Some individual hydrocarbons were determined from dilute exhaust samples and processed by chromatographic techniques to separate methane, ethylene, ethane, acetylene, propylene, propane, benzene and toluene. Higher molecular weight hydrocarbons were not measured. Samples were

TABLE 14. TRANSIENT EMISSIONS SUMMARY FROM BUS CYCLE OPERATION OF THE VOLVO TEST ENGINES

Test Configuration	Cycle Type	Transient Emissions g/kW-hr, (g/hp-hr)				Cycle BSFC[a] kg/kW-hr (lb/hp-hr)	Cycle Work kW-hr (hp-hr)
		HC[d]	CO	NO_x[b]	Part		
Diesel	Bus	1.34 (1.00)	4.59 (3.42)	12.44 (9.28)	0.82 (0.62)	0.294 (0.484)	4.64 (6.21)
Methanol	Bus	1.96 (1.46)	25.56 (19.06)	8.46 (6.31)	0.60 (0.45)	0.566 (0.931)	5.29 (7.10)
Methanol -Catalyst	Bus	0.38 (0.28)	10.43 (7.78)	8.00 (5.97)	0.22 (0.16)	0.548 (0.901)	4.98 (6.68)
Methanol -Cat.-Bp.[c]	Bus	0.31 (0.23)	9.21 (6.87)	9.20 (6.86)	0.24 (0.18)	0.591 (0.971)	4.84 (6.49)
Ethanol	Bus	2.94 (2.19)	24.23 (18.07)	8.11 (6.05)	0.60 (0.45)	0.453 (0.745)	4.88 (6.54)
Ethanol	Bus	0.86 (0.64)	8.15 (6.08)	10.42 (7.77)	0.38 (0.28)	0.478 (0.786)	4.51 (6.05)

---

[a] BSFC is in terms of dual fuel rather than diesel fuel where applicable. Approximately 80%, by mass, of the fuel consumed during a transient cycle was alcohol. Relative heating values are: diesel at 42.90 MJ/kg (18,400 BTU/lb), methanol at 19.88 MJ/kg (8,550 BTU/lb), and ethanol at 27.01 MJ/kg (11,600 BTU/lb)

[b] NO_x values presented here are based on continuous measurement by chemiluminescence. NO_x values for some runs were also computed from bag sample measurement by CL and are reported in the corresponding Appendix. Intake air humidity was controlled - NO_x correction of 1.00 need in all cases of transient NO_x

[c] Bp. stands for backpressure device

[d] HC values reported here are based on indication by HFID (Beckman 402). FID response has been reported to be very low for unburned alcohols and some other species.

TABLE 15. PERCENT OF FUEL CARBON CALCULATED FROM TRANSIENT OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE

Fuel Configuration	Cycle Type	Test Segment, Percent Fuel Carbon[a] 1	2	3	4	Alcohol Portion Used, % Wt.
Methanol	Trans.	50	47	44	51	81.6
	Bus	49	46	48	--	79.3
Methanol -Cat.-Bp.	Trans.	50	48	45	51	80.6
	Bus	50	47	51	--	77.3
Ethanol	Trans.	65	60	58	63	77.6
	Bus	63	60	62	--	73.9
Ethanol -Cat.-Bp.	Trans.	68	61	58	65	76.3
	Bus	66	60	64	--	69.1

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[a] Percent fuel carbon of: No. 2 Diesel is typically 87 percent by wt.
Methanol ≈ 38%
Ethanol ≈ 52%

processed from cold- and hot-start transient operation, and from seven individual modes of steady-state operation. Results from transient operation in the diesel, methanol, methanol-catalyst, ethanol, and ethanol-catalyst configurations are summarized in Table 16. Steady-state results are given in Tables 17, 18, 19 and 20 for the diesel, methanol, methanol-catalyst and ethanol+water configurations, respectively. Of all the individual hydrocarbons mentioned above, methane and ethylene were predominant. Relatively small concentrations of ethane, acetylene, propylene, and benzene were indicated by the procedure. No propane was detected. In most cases toluene was detected, but chromatographic interference, thought to be caused by unburned fuel, makes it difficult to verify the presence of benzene and toluene. As a matter of convenience for comparison purposes, "total" individual hydrocarbons are given for transient operation in Table 16 and are merely the sum of the individual hydrocarbon concentrations, excluding toluene. There is little or no difference between cold-start and hot-start transients, except where the catalyst was used.

TABLE 16. INDIVIDUAL HYDROCARBONS^{b} FROM TRANSIENT OPERATION OF THE VOLVO TEST ENGINES

Test Config.	Trans. Cycle	Units	Individual Hydrocarbon							IHC "Total"^{d}
			Methane	Ethylene	Ethane	Acetylene	Propylene	Benzene	Toluene^{c}	
Diesel	Cold Start	mg/test	220	1600	46	240	530	180	--	2800
		mg/kW-hr	21	160	4.5	23	52	18		280
		mg/kg	69	520	15	75	170	59		910
	Hot Start	mg/test	150	1000	--	--	--	--	--	1150
		mg/kW-hr	14	95						110
		mg/kg	49	330						380
Methanol	Cold Start	mg/test	360	840	20^{a}	7.5^{a}	360	140	1600	1700
		mg/kW-hr	33	76	1.8	.7	33	13	140	160
		mg/kg	59	140	3.2	1.2	59	23	250	290
	Hot Start	mg/test	400	1200	24^{a}	2.1^{a}	470	68	800	2200
		mg/kW-hr	35	100	2.1	.2	41	5.9	70	180
		mg/kg	66	200	4.0	.4	79	11	130	360
Methanol -Catalyst	Cold Start	mg/test	440	550	--	--	120	23^{a}	450	1100
		mg/kW-hr	40	50			11	2.1	41	100
		mg/kg	70	87			20	3.9	72	180
	Hot Start	mg/test	300	300	17^{a}	--	41	--	150	660
		mg/kW-hr	27	27	1.5		3.7		13	60
		mg/kg	48	48	2.8		6.9		24	110
Ethanol	Cold Start	mg/test	1200	4300	53	420	480	320	500	6800
		mg/kW-hr	110	370	4.6	37	42	28	44	600
		mg/kg	240	830	10	82	93	63	98	1300
	Hot Start	mg/test	1200	4600	64	440	480	160	260	6900
		mg/kW-hr	100	400	5.6	39	42	14	23	600
		mg/kg	240	950	13	91	99	33	54	1426
Ethanol -Cat.-Bp.	Cold Start	mg/test	1200	1300	69	120	--	--	230	2700
		mg/kW-hr	120	120	6.6	12			22	260
		mg/kg	250	270	14	25			47	560
	Hot Start	mg/test	1000	1100	52	84	--	--	200	2200
		mg/kW-hr	98	100	4.9	8.0			19	210
		mg/kg	220	230	11	18			44	479

---

[a] Trace amounts, relative to resolution of procedure. Presence is questionable

[b] No propane detected

[c] These values are likely to vary as much as ± 500 mg/test. It is doubtful that toluene was formed and these values were likely caused by unknown interference

[d] Toluene was not used in the "Total," due to the significant uncertainty of its presence.

TABLE 17. INDIVIDUAL HYDROCARBONS FROM MODAL OPERATION OF THE VOLVO TD-100C DIESEL ENGINE[a]

		RPM and PERCENT LOAD IN MODE						
	Units	1400 2%	1400 50%	1400 100%	Idle	2200 100%	2200 50%	2200 2%
Methane	mg/hr	1200	--	--	980	--	--	2100
	mg/kW-hr	600			--			620
	mg/kg fuel	310			830			230
Ethylene	mg/hr	6900	2000	2500	1800	6500	5700	17000
	mg/kW-hr	3400	31	19	--	36	64	5000
	mg/kg fuel	1800	130	86	1500	150	230	1900
Acetylene	mg/hr	690	--	--	--	--	--	2000
	mg/kW-hr	340						590
	mg/kg fuel	180						220
Propylene	mg/hr	2500	--	--	--	--	2100	6500
	mg/kW-hr	1200					24	1900
	mg/kg fuel	640					83	710

---

[a] IHC procedure also separates ethane, propane, benzene and toluene. No propane, acetylene, or toluene were detected. Dilute exhaust samples were taken with CVS flowrates of 2000 CFM for Idle and the 2% loads, 3000 CFM for the 50% loads, and 5000 CFM for 100% loads.

TABLE 18. INDIVIDUAL HYDROCARBONS FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH METHANOL[b]

		RPM and PERCENT LOAD IN MODE						
	Units	1400 2%	1400 50%	1400 100%	Idle	2200 100%	2200 50%	2200 2%
Methane	mg/hr	--[a]	--[a]	1500	240	--[a]	--[a]	620
	mg/kW-hr			11	--			150
	mg/kg fuel			25	210			71
Ethylene	mg/hr	4800	1100	1400	740	7400	2200	7400
	mg/kW-hr	1700	16	100	--	41	24	1800
	mg/kg fuel	1200	40	23	630	88	49	850
Acetylene	mg/hr	370	--	--	--	370	--	400
	mg/kW-hr	130				2		98
	mg/kg fuel	89				4		46
Propylene	mg/hr	1100	--	--	--	2300	--	2400
	mg/kW-hr	390				13		590
	mg/kg fuel	260				27		280

---

[a] Background levels exceeded sample levels

[b] IHC procedure also separated ethane, propane, benzene and toluene. Small concentrations, near the limits of detectability, of ethane, benzene and toluene were noted, but their presence is doubtful. Propane was not detected. Dilute exhaust samples were taken with CVS flowrate of 3000 CFM, nominal.

TABLE 19. INDIVIDUAL HYDROCARBONS FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH METHANOL AND CATALYST[a]

		RPM and PERCENT LOAD IN MODE						
	Units	1400 2%	1400 50%	1400 100%	Idle[b]	2200 100%	2200 50%	2200 2%
Methane	mg/hr	1200	1300	970	210	880	800	3100
	mg/kW-hr	430	19	7	--	5	9	820
	mg/kg fuel	270	47	16	170	11	18	310
Ethylene	mg/hr	2200	363	181	410	570	620	2700
	mg/kW-hr	790	5	1	--	3	7	710
	mg/kg fuel	500	13	3	340	7	14	270
Acetylene	mg/hr	--	--	--	--	--	--	--
	mg/kW-hr							
	mg/kg fuel							
Propylene	mg/hr	--	--	--	--	--	--	440
	mg/kW-hr							120
	mg/kg fuel							43

---

[a] IHC procedure also separates ethane, propane, benzene and toluene. No propane, acetylene, benzene or toluene were detected during operation with catalyst.

[b] This idle condition was run without the backpressure device. Another sample from idle with the backpressure device operable was taken but none of these species were detected.

TABLE 20. INDIVIDUAL HYDROCARBONS FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH ETHANOL + WATER[b]

		RPM and PERCENT LOAD IN MODE						
	Units	1400 2%	1400 50%	1400 100%	Idle[c]	2200 100%	2200 50%	2200 2%
Methane	mg/hr	--[a]	7100	24000	240	2900	5500	2500
	mg/kW-hr		110	180	--	15	58	650
	mg/kg fuel		270	400	210	31	120	270
Ethylene	mg/hr	5000	6400	22000	740	9200	3200	12000
	mg/kW-hr	1800	96	160	--	49	34	3000
	mg/kg fuel	1200	240	370	630	100	68	1300
Ethane	mg/hr	--	440	850	--	390	--	410
	mg/kW-hr		7	6		2		110
	mg/kg fuel		16	14		4		45
Acetylene	mg/hr	--	1200	1600	--	--	--	1300
	mg/hW-hr		17	12				340
	mg/kg fuel		43	28				140
Propylene	mg/hr	1200	--	--	--	--	--	2900
	mg/kW-hr	450						760
	mg/kg fuel	310						320

---

[a] Background level exceeded sample level

[b] IHC procedure also separates propane, benzene and toluene, but none of these were detected. Dilute samples were taken with CVS flowrates of 6000 CFM at 100% conditions and 2000 CFM at all other conditions

[c] Idle data duplicated from methanol configuration

In comparing the diesel engine to the dual-fuel engine, it should be noted that the diesel engine uses direct injection of diesel fuel into the center of the combustion chamber; whereas, the dual-fuel engine uses the smaller pilot injection of diesel tangent to the swirl of the combustion chamber. This point is especially important in comparing emissions at idle, and at light load conditions like 1400 rpm/2 percent load, where only diesel fuel is consumed. The diesel engine shows higher emissions of methane and ethylene at idle and light loads than the dual-fuel configuration. From the transient data, the ethanol configuration produced the highest "total" individual hydrocarbons, primarily due to the high emission rates of ethylene. The catalyst had little effect on methane, but it reduced ethylene significantly. Most levels of the individual hydrocarbons were relatively low, except that the ethanol+water configuration showed high levels of methane and ethylene.

3. Unburned Alcohols

Since the FID response is typically low for alcohols, it was important to determine the quantity of unburned alcohol in the exhaust by another procedure. Table 21 summarizes the results from analysis of unburned alcohols during both transient FTP and bus cycle testing. Results of modal testing are given in Table 22. Unburned methanol was trapped in a wet bubbler containing water, and unburned ethanol was determined from dilute exhaust bag samples. Both samples were processed through the appropriate GC procedure.

There was not much difference in alcohol emissions between the cold-start and hot-start transients. The catalyst reduced the unburned alcohol for both fuels. There was more unburned alcohol from the methanol configuration than from the ethanol configuration. In steady-state testing, the bulk of the unburned alcohol occurred at 50 percent load conditions and at the 2200 rpm/2 percent load condition. The catalyst was very effective in oxidizing the unburned alcohols at the 100 percent load conditions and at the 2200 rpm/50 percent load condition. No alcohol consumption was noted during idle or during the 1400 rpm/2 percent load condition. Considering both test procedures, transient and steady-state, less unburned ethanol was emitted (in ethanol-fueled configurations) than unburned methanol (in methanol-fueled configurations).

4. Aldehydes

Aldehydes were determined by the DNPH procedure, which detects formaldehyde, acetaldehyde, acetone, isobutyraldehyde, methylethylketone, crotonaldehyde, hexanaldehyde, and benzaldehyde. Samples were taken from dilute exhaust during transient operation, while samples of raw exhaust were taken during steady-state operation. The procedure was intended for use with raw exhaust, and it is difficult to obtain a concentrated sample from the dilute exhaust within the 20 minute duration of the transient cycle or the 14-minute bus cycle. Samples were taken over 11 modes

TABLE 21. UNBURNED ALCOHOL SUMMARY FROM TRANSIENT OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE

Test Configuration	Transient Cycle	mg/test	mg/kw-hr	mg/kg fuel[a]
Methanol	Cold Start	52000	4700	8400
	Hot Start	56000	4900	9300
	Composite	55000	4900	9200
	Bus	19000	4100	6900
Methanol -Catalyst	Cold Start	13000	1200	2200
	Hot Start	9600	840	1500
	Composite	10000	890	1600
	Bus	4300	890	1500
Ethanol	Cold Start	25000	2200	4900
	Hot Start	26000	2300	5400
	Composite	26000	2300	5300
	Bus	11000	2300	5000
Ethanol -Catalyst	Cold Start	7000	670	1400
	Hot Start	4700	450	1000
	Composite	5000	480	1100
	Bus	3900	860	1800

---

[a] Fuel refers to dual fuel used, which has a lower heating value than diesel fuel alone

TABLE 22. UNBURNED ALCOHOL SUMMARY FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE

Test Config.	Units	RPM and PERCENT LOAD IN MODE						
		1400[a] 2%	1400 50%	1400 100%	Idle[a]	2200 100%	2200 100%	2200 2%
Methanol	$\mu g/m^3$ exh.	1100	300000	16000[b]	---	160000	700000	370000
	mg/hr	380	130000	9400		150000	500000	200000
	mg/kW-hr	140	1900	69		830	5300	49000
	mg/kg fuel[c]	91	4700	150		1800	1000	23000
Methanol -Catalyst	$\mu g/m^3$ exh.	5700	250000[d]	780	1400[e]	32000	250000	180000
	mg/hr	2000	110000	460	150	30000	180000	94000
	mg/kW-hr	710	1600	3.3	---	170	1900	25000
	mg/kg fuel[c]	160	4000	7.7	120	360	4100	9300
Ethanol + Water	$\mu g/m^3$ exh.		250000	31000	---[f]	52000	140000	210000
	mg/hr		110000	18000		51000	100000	120000
	mg/kW-hr		1600	130		270	1100	31000
	mg/kg fuel[c]		4000	4000		560	2200	13000

---

[a] No alcohol consumption was noted during idle or during 1400/2% condition

[b] This value was based on an incomplete sample (1 of 2 bubblers), and may be atypically low

[c] Computed on the basis of dual fuel, including water

[d] This value was much larger than expected on the basis of 13-mode HC emissions, and should be interpreted with caution

[e] No methanol is introduced during idle, so it is assumed that this value is a result of uncertainty in the quantitative procedure near the detection limit

[f] Idle data duplicated from methanol configuration

of the 13-mode steady-state procedure (idle was only sampled once) in the methanol and the methanol-catalyst configurations. An additional aldehyde sample was taken at idle with the dual-fuel engine backpressure device engaged. Based on the accuracy of the DNPH procedure and the level of effort required to process the samples, steady-state characterization of aldehydes was reduced to include 7 modes of steady-state operation of the diesel and the ethanol+water test configurations.

Of the compounds detectable by the DNPH procedure, only formaldehyde, acetaldehyde, hexanaldehyde and benzaldehyde were prevalent. The presence of benzaldehyde is suspect, in that it is often found as an artifact of the procedure itself. Summaries of the aldehyde results from transient cycle and bus cycle operation are given in Tables 23 and 24, respectively. Summaries of aldehyde results from steady-state operation in diesel, methanol, methanol-catalyst and ethanol+water configurations are given in Tables 25, 26, 27, and 28, respectively.

For a given test configuration, there is little or no difference in aldehyde emissions between the cold-start and the hot-start transient cycles conducted without the catalyst. The diesel configuration emitted relatively low levels of aldehydes. The methanol configuration had higher aldehydes, primarily higher formaldehyde, than the diesel configuration. The ethanol configuration also had higher aldehydes than the diesel configuration, the major differences being higher formaldehyde and acetaldehyde. With methanol, the catalyst reduced acetaldehyde during transient operation, but tended to increase formaldehyde. With ethanol, the catalyst reduced the levels of transient cycle formaldehyde, but increased acetaldehyde. The same trends can be noted for bus cycle operation.

During steady-state operation, aldehydes were higher with the dual-fuel engine on methanol than with the diesel engine. With ethanol+water, formaldehyde was formed in about the same amounts as with the methanol configuration, but more acetaldehyde was produced. The effects of the catalyst were mixed on steady-states run with methanol. Aldehydes were increased at the light loads and idle, but were reduced at the high loads where the catalyst temperature was sufficient to oxidize the unburned fuel species. Use of the backpressure device at idle, in conjunction with the catalyst, appears to have reduced the levels of aldehydes detected.

5. Phenols

Phenols were determined using a wet chemistry procedure as outlined in Section III.E.1 and described in detail in Reference 8. The detection of individual phenols in either dilute or raw engine exhaust appears to be quite variable. In the early stages of this program, it was uncertain whether better results would be obtained from the filtered sample procedure or from the unfiltered sample procedure. It was reasoned that filtering the particulate out of the exhaust sample at 190°C (375°F) could keep the sample clear of particulate, causing less interference.

TABLE 23. SUMMARY OF ALDEHYDES[a] FROM TRANSIENT OPERATION OF THE VOLVO TEST ENGINES

Test Config.	Trans. Cycle	Units	Formaldehyde	Acetaldehyde	Benzaldehyde[b]	"Total"[c] Aldehydes
Diesel	Cold Start	mg/test	180	--	76	180
		mg/kW-hr	18	--	7.4	18
		mg/kg fuel	59	--	24	59
	Hot Start	mg/test	140	--	98	140
		mg/kW-hr	13	--	9.3	13
		mg/kg fuel	46	--	33	46
Methanol	Cold Start	mg/test	1900	490	2900	2400
		mg/kW-hr	190	48	280	240
		mg/kg fuel	330	84	490	414
	Hot Start	mg/test	2400	210	1600	2600
		mg/kW-hr	230	21	160	250
		mg/kg fuel	430	38	290	470
Methanol -Cat.-Bp.	Cold Start	mg/test	2600	120[d]	750	2700
		mg/kW-hr	250	11	73	260
		mg/kg fuel	400	18	120	420
	Hot Start	mg/test	3000	20[d]	160	3000
		mg/kW-hr	260	1.8	14	260
		mg/kg fuel	470	3.2	24	470
Ethanol	Cold Start	mg/test	2000	1500	2500	3500
		mg/kW-hr	170	130	210	300
		mg/kg fuel	380	280	480	660
	Hot Start	mg/test	1700	900	3000	2600
		mg/kW-hr	150	80	260	230
		mg/kg fuel	350	180	610	530
Ethanol -Cat.-Bp.	Cold Start	mg/test	820	3200	--	4200
		mg/kW-hr	80	300	--	380
		mg/kg fuel	170	660	--	830
	Hot Start	mg/test	370	2200	360	2600
		mg/kW-hr	33	200	32	230
		mg/kg fuel	75	440	73	520

---

[a] DNPH procedure also separates acetone, isobutyraldehyde, methylethylketone, crotonaldehyde, and hexanaldehyde. No methylethylketone, crotonaldehyde or hexanaldehyde were found. Acetone and isobutryaldehyde appeared sporadically and were very low. The presence of acetone is also difficult to assess because of the potential for contamination of the DNPH procedure by acetone background.

[b] Benzaldehyde may be an artifict of the DNPH procedure and it appeared sporadically

[c] Benzaldehyde is not included in the "total" because of the uncertainty of its presence

[d] Trace amounts relative to the resolution of this procedure.

TABLE 24. SUMMARY OF ALDEHYDES[a] FROM BUS CYCLE OPERATION OF THE VOLVO TEST ENGINES

Test Config.	Cycle	Units	Formaldehyde	Acetaldehyde	Benzaldehyde	"Total" Aldehydes[c]
Diesel	Bus	mg/test	96	--	--	96
		mg/kW-hr	21	--	--	21
		mg/kg fuel	70	--	--	70
Methanol	Bus	mg/test	1300	840	3400	2100
		mg/kW-hr	280	180	740	460
		mg/kg fuel	460	310	1200	770
Methanol -Cat.-Bp.	Bus	mg/test	1800	--	--	1801
		mg/kW-hr	370	--	--	370
		mg/kg fuel	620	--	--	620
Ethanol	Bus	mg/test	2400	1500	2700	3900
		mg/kW-hr	490	310	540	800
		mg/kg fuel	1100	680	1200	1800
Ethanol -Cat.-Bp.	Bus	mg/test	590	1100	--	1700
		mg/kW-hr	140	250	--	380
		mg/kg fuel	270	510	--	780

---

[a] DPHN procedure also separates acetone, isobutyraldehyde, methylethylketone, crotonaldehyde, and hexanaldehyde. No methylethylketone, crotonaldehyde or hexanaldehyde were found. Acetone and isobutryaldehyde appeared sporadically and were very low. The presence of acetone is also dificult to assess because of the potential for contamination of the DNPH procedure by acetone background.

[b] Benzaldehyde may be an artifact of the DNPH procedure and it appeared sporadically

[c] Benzaldehyde is not included in the "total" because of the uncertainty of its presence

TABLE 25. SUMMARY OF ALDEHYDES FROM MODAL OPERATION OF THE VOLVO TD-100C DIESEL ENGINE[a]

		RPM and PERCENT LOAD IN MODE						
	Units	1400 2%	1400 50%	1400 100%	Idle	2200 100%	2200 50%	2200 2%
Formaldehyde	µg/m^3 exh.	3400	1800	1200	3100	780	1300	3800
	mg/hr	1200	720	630	360	750	980	2200
	mg/kW-hr	600	11	4.9	---	4.2	11	650
	mg/kg fuel	310	48	22	310	17	39	240
Acetaldehyde	µg/m^3 exh.	190	---	---	---	---	---	19[b]
	mg/hr	68						11
	mg/kW-hr	34						3.2
	mg/kg fuel	17						1.2
Hexanaldehyde	µg/m^3 exh.	---	370	180	---	270	---	---
	mg/hr		150	94		260		
	mg/kW-hr		2.3	0.72		1.5		
	mg/kg fuel		10	3.2		5.9		
Benzaldehyde[c]	µg/m^3 exh.	400	240	310	400	---	420	640
	mg/hr	140	96	160	47		320	370
	mg/kW-hr	70	1.5	1.2	---		3.6	110
	mg/kg fuel	36	6.4	5.5	40		13	40

---

[a] No acetone or methylethylketone was noted for either fuel configuration Isobutyraldehyde, crotonaldehyde and hexanaldehyde appeared sporadically, and at low levels

[b] Trace amounts, relative to the resolution of this procedure

[c] Benzaldehyde may be an artifact of the DNPH procedure

TABLE 26. SUMMARY OF ALDEHYDES FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH METHANOL[a]

		RPM and PERCENT LOAD IN MODE										
	Units	1400 2%	1400 25%	1400 50%	1400 75%	1400 100%	Idle	2200 100%	2200 75%	2200 50%	2200 25%	2200 2%
Formaldehyde	$\mu g/m^3$ exh.	2400	3800	10000	7100	3000	730	2000	17000	32000	35000	10000
	mg/hr	820	1400	4200	3800	1800	85	1900	15000	23000	2300	5300
	mg/kW-hr	290	41	62	36	13	---	10	110	250	490	1300
	mg/kg fuel	200	89	150	81	30	73	23	210	520	730	600
Acetaldehyde	$\mu g/m^3$ exh.	690	29[b]	260	350	---	---	---	100	600	810	1100
	mg/hr	240	11	110	180				80	440	520	600
	mg/kW-hr	86	0.31	1.6	1.7				0.62	4.7	11	150
	mg/kg fuel	56	0.70	4.0	3.8				1.2	10	17	69
Benzaldehyde[c]	$\mu g/m^3$ exh.	---	2600	860	900	140	800	17[b]	1300	900	4500	1600
	mg/hr		1000	360	480	82	93	16	1100	660	2900	850
	mg/kw-hr		29	5.3	4.6	0.60	---	0.09	7.7	7.1	61	200
	mg/kg fuel		64	13	10	1.3	70	0.19	15	15	93	98

---

[a] No acetone or methylethylketone was noted for either fuel configuration Isobutyraldehyde, crotonaldehyde and hexanaldehyde appeared sporadically, and at low levels

[b] Trace amounts, relative to the resolution of this procedure

[c] Benzaldehyde may be an artifact of the DNPH procedure

TABLE 27. SUMMARY OF ALDEHYDES FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH METHANOL AND CATALYST[a]

		RPM and PERCENT LOAD IN MODE											
		1400	1400	1400	1400	1400		2200	2200	2200	2200	2200	Idle
	Units	2%	25%	50%	75%	100%	Idle	100%	75%	50%	25%	2%	w/Bp.
Formaldehyde	$\mu g/m^3$ exh.	3000	3000	3700	1500	1100	2700	2600	45000	61000	59000	17000	1900
	mg/hr	1000	1100	1600	790	650	300	2500	40000	45000	38000	8800	170
	mg/kW-hr	360	31	23	7.5	4.7	---	14	280	480	810	2300	---
	mg/kg fuel	230	69	57	18	11	250	30	580	1000	1300	870	98
Acetaldehyde	$\mu g/m^3$ exh.	140	63[b]	---	---	---	150	63[b]	230	340	460	3600	33[b]
	mg/hr	48	24				17	60	200	250	300	1900	2.9
	mg/kW-hr	17	0.69				---	0.33	1.4	2.7	6.4	500	---
	mg/kg fuel	11	1.5				14	0.72	2.9	5.7	10	190	1.7
Benzaldehyde[c]	$\mu g/m^3$ exh.	620	650	320	---	230	1200	290	5400	1700	3900	2100	140
	mg/hr	210	250	140		140	130	270	4800	1200	2500	1100	13
	mg/kW-hr	75	7.1	2.1		1.0	---	1.5	34	13	53	290	---
	mg/kg fuel	47	16	5.0		2.4	110	3.2	70	27	87	110	7.5

---

[a] No acetone or methylethylketone was noted for either fuel configuration Isobutyraldehyde, crotonaldehyde and hexanaldehyde appeared sporadically, and at low levels

[b] Trace amounts, relative to the resolution of this procedure

[c] Benzaldehyde may be an artifact of the DNPH procedure

TABLE 28. SUMMARY OF ALDEHYDES FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH ETHANOL + WATER

		RPM and PERCENT LOAD IN MODE						
	Units	1400 2%	1400 50%	1400 100%	Idle[a]	2200 100%	2200 50%	2200 2%
Formaldehyde	μg/m^3 exh.	3800	2000	5200	730	11000	14000	48000
	mg/hr	1300	830	2000	85	11000	10000	2600
	mg/kW-hr	470	13	22	--	60	110	700
	mg/kg fuel	320	31	51	73	12	220	290
Acetaldehyde	μg/m^3 exh.	900	380	510	--	13000	16000	2800
	mg/hr	320	1600	300		13000	1200	1600
	mg/kW-hr	110	24	2.2		68	120	410
	mg/kg fuel	78	59	5.0		140	250	170
Hexanaldehyde	μg/m^3 exh.	--	210	310	--	170	110	--
	mg/hr		87	180		170	78	
	mg/kW-hr		1.3	1.3		0.92	0.82	
	mg/kg fuel		3.3	3.1		1.9	1.6	
Benzaldehyde[b]	μg/m^3 exh.	400	--	100	800	110	240	170
	mg/hr	140		61	93	110	180	92
	mg/kW-hr	50		0.45	--	0.59	1.9	24
	mg/kg fuel	35		1.0	79	1.2	3.8	10

---

[a] Idle data duplicated from methanol configuration

[b] Benzaldehyde may be an artifact of the DNPH procedure

The unfiltered sample was also considered because it was thought that the phenols might be attached to the particulate, and would be extracted in the collection bubbler. Both filtered and unfiltered samples were processed in the methanol and methanol-catalyst configurations, for both transient and steady-state operation. Based on similarities between the methanol configuration and the ethanol+water configuration, no samples were processed for the ethanol+water configuration. By the time the diesel engine was to be characterized, it was decided to process only filtered phenol samples, on the basis that the filtered phenol procedure had been shown to have higher recovery factors during qualification experiments.(8)

Summaries of filtered phenol results are given in Table 29 for transient operation, and in Tables 30, 31, and 32 for steady-state operation. Results from the unfiltered procedure are given in Table 33 for transient operation, and in Tables 34 and 35 for steady-state operation. Fewer "total" phenols were generated with methanol than with either ethanol or diesel during transient operation. The filtered phenol data indicate that more highly substituted phenols may be formed with the catalyst. At idle, the catalyst appears to have little effect. Using the backpressure device and catalyst at idle, the phenols were reduced slightly. It is difficult to decide whether to attribute changes in emissions to the back-pressure on the engine, or to its effect of slightly raising the temperature of the catalyst. Considering the relatively uncertain accuracy of the phenol procedure, it is difficult to establish trends from the data.

6. Total Hydrocarbons - FID Response

As mentioned in several places throughout this report, total hydrocarbons were measured using a Beckman Model 402 heated flame ionization detector. References (6 and 7) have shown that the FID response to unburned alcohols and some species of unregulated emissions is quite variable, depending on FID construction. The reported FID response factors, given in Table 9 of Section III.E.1 from Reference 6, were used in conjunction with transient cycle "total" emission rates of unburned alcohols, individual hydrocarbons, individual aldehydes, and individual phenols to compute a "total" hydrocarbon emission rate. These "total" hydrocarbons, along with the hydrocarbons measured by continuous HFID during transient testing, are given in Table 36.

For the diesel configuration, unburned fuel was not measured directly as it was for the unburned alcohols. However, the HFID response to unburned diesel fuel-like constituents is assumed to be 1.0 by design; and unburned fuel is therefore accounted for in the continuous measurement of total hydrocarbons by HFID. The "total" (unregulated) hydrocarbons for the diesel configuration are substantially lower than the HFID total hydrocarbons due to the absence of a "total unburned fuel" in the summation. This would imply that levels of unburned diesel fuel-like constituents could be about 1200 mg/kW-hr for the cold-start, and about 950

TABLE 29. SUMMARY OF PHENOLS (FILTERED) FROM TRANSIENT OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE

Test Config.	Trans. Cycle	Units	Phenol	Salicyl- aldehyde	m-cresol + p-cresol	5[a]	2,3,5 tri- methylphenol	2,3,5,6[b]	2npp[c]	"Total" Phenol
Diesel	Cold Start	mg/test	--	240	120	26	57	23	490	960
		mg/kW-hr		23	12	2.5	5.5	2.2	48	93
		mg/kg		75	39	8.1	18	7.2	156	300
	Hot Start	mg/test	--	32	--	--	12	--	230	270
		mg/kW-hr		2.9			1.1		21	25
		mg/kg		10			3.9		75	89
Methanol	Cold Start	mg/test	--	--	--	--	19[d]	--	170	190
		mg/kW-hr					1.8		16	18
		mg/kg					3.2		29	32
	Hot Start	mg/test	--	--	64	--	--	14[d]	180	260
		mg/kW-hr			6.2			1.4	17	25
		mg/kg			12			2.6	32	47
Methanol -Cat.-Bp.	Cold Start	mg/test	--	--	170	120	--	--	440	730
		mg/kW-hr			16	11			42	69
		mg/kg			26	18			67	110
	Hot Start	mg/test	--	--	200	71	--	--	230	500
		mg/kW-hr			18	6.3			20	44
		mg/kg			31	11			35	77
Ethanol	Cold Start	mg/test	32	38	13[d]	190	8.4[d]	630	23[d]	930
		mg/kW-hr	2.8	3.4	1.1	17	0.7	56	2.0	83
		mg/kg	6.2	7.5	2.5	37	1.6	120	4.5	180
	Hot Start	mg/test	27	--	--	110	12	280	--	430
		mg/kW-hr	2.4			9.6	1.0	24		37
		mg/kg	5.5			22	2.4	57		87
Ethanol -Cat.-Bp.	Cold Start	mg/test	--	--	230	34	--	--	620	880
		mg/kW-hr			22	3.2			59	84
		mg/kg			48	6.9			130	180
	Hot Start	mg/test	--	--	100	--	--	36	120	260
		mg/kW-hr			9.8			3.4	11	24
		mg/kg			22			7.7	25	55

---

[a] p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethylphenol

[b] 2,3,5,6-tetramethylphenol

[c] 2-n-propylphenol

[d] These levels are very low and are close to the minimum detectable level; their presence and quantity are difficult to assess.

TABLE 30. SUMMARY OF PHENOLS (FILTERED) FROM MODAL OPERATION OF THE VOLVO TD-100C DIESEL ENGINE

		RPM and PERCENT LOAD IN MODE		
	Units	1400 50%	Idle	2200 100%
Phenol	$\mu g/m^3$	130	--	--
	mg/hr	52		
	mg/kW-hr	0.81		
	mg/kg fuel	3.5		
Salicyl-aldehyde	$\mu g/m^3$	190	200	80
	mg/hr	76	23	76
	mg/kW-hr	1.2	--	0.42
	mg/kg fuel	5.1	19	1.7
m-cresol + p-cresol	$\mu g/m^3$	140	--	160
	mg/hr	56		150
	mg/kW-hr	0.87		0.84
	mg/kg fuel	3.7		3.4
5[a]	$\mu g/m^3$	--	--	--
	mg/hr			
	mg/kW-hr			
	mg/kg fuel			
2,3,5 tri-methyl phenol	$\mu g/m^3$	240	61	36[b]
	mg/hr	96	7.2	34
	mg/kW-hr	1.5	--	0.19
	mg/kg fuel	6.4	6.1	0.78
2,3,5,6[c]	$\mu g/m^3$	--	--	--
	mg/hr			
	mg/kW-hr			
	mg/kg fuel			
2 npp[d]	$\mu g/m^3$	7300	310	9700
	mg/hr	2900	36	9300
	mg/kW-hr	45	--	52
	mg/kg fuel	190	31	210

---

[a] p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethylphenol

[b] These levels are very low and are close to the minimum detectable level; their presence and quantity are difficult to assess.

[c] 2,3,5,6-tetramethylphenol

[d] 2-n-propylphenol

TABLE 31. SUMMARY OF PHENOLS (FILTERED) FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH METHANOL

		RPM and PERCENT LOAD IN MODE						
	Units	1400 2%	1400 50%	1400 100%	Idle	2200 100%	2200 50%	2200 2%
Phenol	$\mu g/m^3$	120	140	70	--	44[a]	65	72
	mg/hr	42	59	41		42	48	38
	mg/kW-hr	15	0.87	0.30		0.23	0.51	9.3
	mg/kg fuel	10	2.1	0.67		0.50	1.1	4.4
Salicyl-aldehyde	$\mu g/m^3$	250	--	--	60	--	--	130
	mg/hr	87			7.0			69
	mg/kW-hr	31			--			17
	mg/kg fuel	21			6.0			7.9
m-cresol + p-cresol	$\mu g/m^3$	220	21[a]	71	85	34[a]	47	83
	mg/hr	76	8.9	42	10	33	34	44
	mg/kW-hr	27	0.31	0.31	--	0.18	0.36	11
	mg/kg fuel	18	0.69	0.69	8.5	0.39	0.76	5.1
5[b]	$\mu g/m^3$	570	240	92	270	61	--	300
	mg/hr	200	100	54	31	59		160
	mg/kW-hr	71	1.5	0.39	--	0.33		39
	mg/kg fuel	48	3.6	0.89	26	0.70		18
2,3,5 tri-methyl phenol	$\mu g/m^3$	84	--	--	42[a]	--	7.2[a]	36[a]
	mg/hr	29			4.9		5.3	19
	mg/kW-hr	10			--		0.06	4.6
	mg/kg fuel	7.0			4.2		0.12	2.2
2,3,5,6[c]	$\mu g/m^3$	--	33[a]	--	26[a]	--	42[a]	12[a]
	mg/hr		14		3.0		31	6.4
	mg/kW-hr		0.21		--		0.33	1.6
	mg/kg fuel		0.51		2.6		0.69	0.7
2 npp[d]	$\mu g/m^3$	3400	2800	3300	2500	640	1500	780
	mg/hr	1200	1200	1900	290	620	1100	420
	mg/kW-hr	430	18	14	--	3.4	12	102
	mg/kg fuel	290	43	31	250	7.4	25	48

[a] These levels are very low and are close to the minimum detectable level; their presence and quantity are difficult to assess.

[b] p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethylphenol

[c] 2,3,5,6-tetramethylphenol

[d] 2-n-propylphenol

TABLE 32. SUMMARY OF PHENOLS (FILTERED) FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH METHANOL AND CATALYST

		RPM and PERCENT LOAD IN MODE							
	Units	1400 2%	1400 50%	1400 100%	Idle	2200 100%	2200[a] 50%	2200 2%	Idle + B. P.
Phenol	μg/m^3	27[a]	80	57[a]	220	35[a]	--	--	76
	mg/hr	9.3	34	34	24	33	--		6.8
	mg/kW-hr	3.3	0.50	0.25	--	0.18	--		--
	mg/kg fuel	2.1	1.2	0.57	20	0.40	--		3.9
Salicyl-aldehyde	μg/m^3	79	--	--	71	--	--	--	--
	mg/hr	27			7.8		--		
	mg/kW-hr	10			--		--		
	mg/kg fuel	6.1			6.4		--		
m-cresol + p-cresol	μg/m^3	98	75	54[a]	49[a]	32[a]	--	--	110
	mg/hr	34	32	32	5.4	30	--		9.8
	mg/kW-hr	12	0.47	0.23	--	0.17	--		--
	mg/kg fuel	7.7	1.1	0.54	4.5	0.36	--		5.6
5[b]	μg/m^3	240	--	230	230	61	--	170	89
	mg/hr	83		--	25	58	--	88	80
	mg/kW-hr	30		--	--	-.32	--	23	--
	mg/kg fuel	19		--	21	0.69	--	8.7	4.6
2,3,5 tri-methyl phenol	μg/m^3	39[a]	21[a]	31[a]	54[a]	--	--	13[a]	52[a]
	mg/hr	13	9.0	18	6.0		--	6.8	4.6
	mg/kW-hr	4.6	0.13	0.13	--		--	1.8	--
	mg/kg fuel	2.9	0.32	0.30	5.0		--	0.67	2.6
2,3,5,6[c]	μg/m^3	34[a]	--	--	--	--	--	--	--
	mg/hr	12					--		
	mg/kW-hr	4.3					--		
	mg/kg fuel	2.7					--		
2 npp[d]	μg/m^3	2000	2200	1200	1700	1600	--	1300	650
	mg/hr	690	950	710	190	1500	--	680	58
	mg/kW-hr	250	14	5.2	--	8.3	--	180	--
	mg/kg fuel	160	34	12	160	18	--	67	33

[a] Sample void

[b] These levels are very low and are close to the minimum detectable level; their presence and quantity are difficult to assess.

[c] p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethylphenol

[d] 2,3,5,6-tetramethylphenol

[e] 2-n-propylphenol

TABLE 33. SUMMARY OF PHENOLS (UNFILTERED) FROM TRANSIENT OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE

Test Config.	Trans. Cycle	Units	Phenol	Salicyl-aldehyde	m-cresol + p-cresol	5 [a]	2,3,5 tri-methylphenol	2,3,5,6 [b]	2npp [c]	"Total"
Methanol	Cold	mg/test	--	15 [d]	--	20 [d]	9.6 [d]	--	120	160
	Start	mg/kW-hr		1.5		1.9	0.9		11	15
		mg/kg		2.6		3.4	1.6		20	28
	Hot	mg/test	--	--	20	37	20	--	220	300
	Start	mg/kW-hr			1.9	3.6	2.0		21	28
		mg/kg			3.5	6.7	3.7		39	53
Methanol	Cold	mg/test	--	--	--	17	--	--	230	250
-Cat.-Bp.	Start	mg/kW-hr				1.6			22	24
		mg/kg				2.5			36	39
	Hot	mg/test	--	--	--	--	--	--	370	370
	Start	mg/kW-hr							33	33
		mg/kg							58	58
Ethanol	Cold	mg/test	11 [d]	--	70	20	4.8 [d]	170	--	280
	Start	mg/kW-hr	1.0		6.1	1.7	.4	15		24
		mg/kg	2.1		14	3.8	.9	34		55
	Hot	mg/test	6.3 [d]	70	--	8.0 [d]	--	270	--	350
	Start	mg/kW-hr	.6	6.2		0.7		24		32
		mg/kg	1.3	14		1.6		55		72
Ethanol	Cold	mg/test	--	--	--	18	--	--	130	150
-Cat.-Bp.	Start	mg/kW-hr				1.7			12	14
		mg/kg				3.7			27	31
	Hot	mg/test	--	23	7.2 [d]	220	7.2 [d]	19	380	660
	Start	mg/kW-hr		2.2	0.7	21	0.7	1.8	36	62
		mg/kg		4.9	1.5	48	1.5	4.1	81	140

---

[a] p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethylphenol

[b] 2,3,5,6-tetramethylphenol

[c] 2-n-propylphenol

[d] These levels are very low and are close to the minimum detectable levels; their presence and quantity are difficult to assess.

TABLE 34. SUMMARY OF PHENOLS (UNFILTERED) FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH METHANOL

		RPM and PERCENT LOAD IN MODE						
	Units	1400 2%	1400 50%	1400 100%	Idle	2200 100%	2200 50%	2200 2%
Phenol	μg/m^3	98	140	--	65	74	120	67
	mg/hr	34	59		7.6	71	88	36
	mg/kW-hr	12	0.87		--	0.39	0.94	8.8
	mg/kg fuel	8.2	2.1		6.5	0.85	2.0	4.1
Salicyl- aldehyde	μg/m^3	140	--	--	98	--	--	130
	mg/hr	49			11			69
	mg/kW-hr	18			--			17
	mg/kg fuel	12			9.4			7.9
m-cresol + p-cresol	μg/m^3	140	99	48[a]	14[a]	25[a]	39[a]	150
	mg/hr	49	42	28	1.6	24	29	80
	mg/kW-hr	18	0.62	0.20	--	0.13	0.02	20
	mg/kg fuel	12	1.5	0.46	1.4	9.29	0.65	9.2
5[b]	μg/m^3	490	210	57	320	--	--	360
	mg/hr	170	89	34	37			190
	mg/kW-hr	61	1.3	0.25	--			46
	mg/kg fuel	41	3.2	0.56	32			22
2,3,5 tri- methyl phenol	μg/m^3	550	19[a]	--	30[a]	--	29[a]	26[a]
	mg/hr	190	8		3		21	14
	mg/kW-hr	68	0.12		--		0.22	3.4
	mg/kg fuel	46	0.29		2.6		0.47	1.6
2,3,5,6[c]	μg/m^3	--	--	--	91	--	48[a]	--
	mg/hr				11		35	
	mg/kW-hr				--		0.37	
	mg/kg fuel				9.4		0.47	
2 npp[d]	μg/m^3	2000	1900	1500	1800	1700	1500	1100
	mg/hr	700	800	880	210	1600	1100	590
	mg/kW-hr	250	12	6.4	--	8.8	12	140
	mg/kg fuel	200	29	14	180	19	25	68

---

[a] These levels are very low and are close to the minimum detectable level; their presence and quantity are difficult to assess

[b] p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethylphenol

[c] 2,3,5,6-tetramethylphenol

[d] 2-n-propylphenol

TABLE 35. SUMMARY OF PHENOLS (UNFILTERED) FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE WITH METHANOL AND CATALYST

		RPM and PERCENT LOAD IN MODE							
	Units	1400 2%	1400 50%	1400 100%	Idle	2200 100%	2200 50%	2200 2%	Idle+ B. P.
Phenol	$\mu g/m^3$	41[a]	--	--	--	740	1200	9.4	81
	mg/hr	14				700	880	4.9	7.2
	mg/kW-hr	5.0				3.9	9.4	1.3	--
	mg/kg fuel	3.2				8.3	20	0.48	4.1
Salicyl-aldehyde	$\mu g/m^3$	--	--	--	--	140	--	--	--
	mg/hr					130			
	mg/kW-hr					0.72			
	mg/kg fuel					1.6			
m-cresol + p-cresol	$\mu g/m^3$	18[a]	29[a]	--	--	260	91	--	140
	mg/hr	6.2	12			250	70		12
	mg/kW-hr	2.2	0.18			1.4	0.5		--
	mg/kg fuel	1.4	0.43			0.3	1.6		6.9
5[b]	$\mu g/m^3$	130	90	24[a]	--	--	--	130	130
	mg/hr	45	39	14				68	12
	mg/kW-hr	16	0.57	0.10				18	--
	mg/kg fuel	10	1.4	0.24				6.7	6.7
2,3,5 tri-methyl phenol	$\mu g/m^3$	26[a]	--	--	--	130	10[a]	--	36[a]
	mg/hr	0.9				120	7.3		3.2
	mg/kW-hr	3.2				0.66	0.08		--
	mg/kg fuel	2.0				1.4	0.17		1.8
2,3,5,6[c]	$\mu g/m^3$	--	--	--	--	150	--	25[a]	--
	mg/hr					140		13	
	mg/kW-hr					0.78		3.4	
	mg/kg fuel					1.7		1.3	
2 npp[d]	$\mu g/m^3$	810	1300	960	1100	700	1300	1600	860
	mg/hr	280	560	570	120	660	950	830	77
	mg/kW-hr	100	8.2	4.1	--	3.7	10	220	--
	mg/kg fuel	63	20	9.6	99	7.9	21	82	44

[a] These levels are very low and are close to the minimum detectable level; their presence and quantity are difficult to assess

[b] p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethylphenol

[c] 2,3,5,6-tetramethylphenol

[d] 2-n-propylphenol

TABLE 36. SUMMARY/COMPARISON OF "TOTAL" UNREGULATED HYDROCARBONS AND HYDROCARBONS MEASURED BY CONTINUOUS HFID DURING TRANSIENT OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE

Configuration	"Total" Unburned Alcohol mg/kw-hr	"Total" Individual Hydrocarbons mg/kw-hr	"Total" Individual Aldehydes mg/kw-hr	"Total" Individual Phenols[a] mg/kw-hr	Sum of "Totals" g/kw-hr	Hydrocarbons Measured by Cont. HFID g/kw-hr
Diesel						
FID Response Fact.[b]	N.A.	1.00	0.05[c]	0.75	--	--
Cold Meas. Total	--	280	18	93	0.39	--
Cold Adj. Total	--	280	0.9	70	0.35	1.58
Hot Meas. Total	--	110	13	25	0.15	--
Hot Adj. Total	--	110	0.7	19	0.13	1.08
Methanol						
FID Response Fact.[b]	0.23	1.00	0.12[c,d]	0.75	--	--
Cold Meas. Total	4700	160	240	18	5.12	--
Cold Adj. Total	1080	160	29	13	1.28	1.98
Hot Meas. Total	4900	180	250	25	5.36	--
Hot Adj. Total	1130	180	30	19	1.36	1.96
Methanol + Cat.						
FID Response Fact.[b]	0.23	1.00	0.06[e]	0.75	--	--
Cold Meas. Total	1200	100	260	69	1.63	--
Cold Adj. Total	280	100	16	52	0.46	0.49[h]
Hot Meas. Total	840	60	260	44	1.20	--
Hot Adj. Total	190	60	16	33	0.30	0.17[h]
Ethanol						
FID Response Fact.[b]	0.46	1.00	0.15[f]	0.75	--	--
Cold Meas. Total	2200	600	300	83	3.18	--
Cold Adj. Total	1010	600	45	62	1.72	2.28
Hot Meas. Total	2300	600	230	37	3.17	--
Hot Adj. Total	1060	600	35	28	1.72	2.27
Ethanol + Cat.						
FID Response Fact.[b]	0.46	1.00	0.24[g]	0.75	--	--
Cold Meas. Total	670	260	380	84	1.39	--
Cold Adj. Total	310	260	91	33	0.69	0.79
Hot Meas. Total	450	210	230	24	0.91	--
Hot Adj. Total	207	210	55	18	0.54	0.60

---

[a] Total phenols were based on "filtered" phenols procedure which has shown better recovery than the unfiltered phenol procedure during procedural qualifications

[b] FID response factors are on a weight basis and were taken directly from reference or interpolated from FID responses given for species of similar molecular structure

[c] Acetaldehyde has an interpolated response of about 0.30, whereas formaldehyde has a response estimated to be about .05

[d] FID response based on 25% acetaldehyde + 75% formaldehyde - weighted for a sum of 0.12

[e] FID response based on 2% acetaldehyde + 98% formaldehyde - weighted for a sum of 0.06

[f] FID response based on 40% acetaldehyde + 98% formaldehyde - weighted for a sum of 0.15

[g] FID response based on 75% acetaldehyde + 25% formaldehyde - weighted for a sum of 0.24

[h] Average of methanol + Cat. and methanol + Cat. + B.P.

mg/kW-hr from the hot-start transient cycles. Considering the alcohol fuel configurations, the "total" (unregulated) hydrocarbons were approximately double the hydrocarbons indicated by the continuous HFID measurement. The most significant contribution to the "total" (unregulated) hydrocarbons was the unburned alcohol emissions followed by the IHC emissions. Contribution of the aldehydes to "total" (unregulated) hydrocarbons was moderate, and the contribution of phenols was insignificant. The "total" hydrocarbons were significantly reduced by the catalyst, which appears to have significantly reduced the unburned alcohol and the IHC emitted by the non-catalyst configurations.

7. Odor - TIA

TIA results were determined using the DOAS analysis of traps which collected compounds related to odor intensity.(8,10) This chromatographic procedure separates an oxygenate fraction (liquid column oxygenates, LCO) and an aromatic fraction (liquid column aromatics, LCA). The TIA values are defined as $\mathrm{TIA} = 1 + \log_{10}$ (LCO, μg/ℓ) or $\mathrm{TIA} = 0.4 + 0.7 \log_{10}$ (LCA μg/ℓ), (TIA by LCO preferred). The procedure was developed for steady-state raw exhaust samples, but was adapted to transient dilute exhaust samples by use of the CVS. Table 37 summarizes the results from transient test operation. TIA results from the diesel transient operation were high for the cold-start, and low for the hot-start. Very little difference in TIA exists between methanol- and ethanol-fueled configurations, with or without catalyst. The catalyst reduced LCA significantly for both methanol and ethanol.

TIA results from steady-state test configurations are given in Table 38, and include 7 modes of methanol and methanol-catalyst operation along with three modes of diesel operation. The TIA values for diesel operation were slightly higher than those for the methanol configuration. TIA values for idle, and for 1400 rpm at 2 percent load, were relatively high for the methanol fuel configuration. The odor index values at these and other modes were significantly reduced with the catalyst, except for the condition at 2200 rpm and 2 percent load, for which an increase was noted.

C. Particulate Emissions

Although heavy-duty diesel particulate emissions are not scheduled to be regulated until 1986, they have been measured for some time and have been recognized as a potential problem in the application of diesel engines. In order to determine particulate emission rates and to characterize the total particulate, samples were collected on several filter media for a variety of analyses which included total mass, sulfate, elemental analysis, particle sizing, and organic extractables. Particulate samples were always taken from the dilute exhaust using a CVS.

TABLE 37. SUMMARY OF TIA BY DOAS[a] FROM TRANSIENT OPERATION OF THE VOLVO TD100A DUAL FUEL ENGINE

Fuel Configuration	Transient Cycle	LCA µg/ℓ	LCO µg/ℓ	TIA
Diesel	Cold Start	29.7	7.20	1.86
	Hot Start	--	1.20	1.08
	Composite	4.24	2.06	1.19
	Bus	10.14	--	1.10[b]
Methanol	Cold Start	2.60	3.30	1.47
	Hot Start	3.70	3.50	1.53
	Composite	3.44	3.30	1.52
	Bus	-	4.17	1.61
Methanol + Catalyst	Cold Start	-	1.59	1.17
	Hot Start	-	2.79	1.45
	Composite	-	2.62	1.41
	Bus	-	1.14	1.06
Ethanol	Cold Start	2.22	4.16	1.60
	Hot Start	1.53	3.18	1.50
	Composite	1.63	3.32	1.51
	Bus	3.36	3.57	1.55
Ethanol + Catalyst	Cold Start	-	3.42	1.53
	Hot Start	-	5.04	1.70
	Composite	-	4.81	1.68
	Bus	-	5.28	1.72

---

[a] These measurements were based on diesel fuel standard. Samples were taken from dilute exhaust of approximately 6:1 for overall transient cycle.

[b] Based on $TIA_{LCA} = 0.4 + 0.7 \log LCA$

TABLE 38. SUMMARY OF TIA BY DOAS FROM MODAL OPERATION OF THE VOLVO TD-100A DUAL-FUEL ENGINE AND THE TD-100C DIESEL ENGINE

Modal Condition rpm/load %	Fuel Configuration	LCA µg/ℓ	LCO µg/ℓ	TIA
1400/2	Methanol	70.	34.	2.5
	Meth-Cat.	16.	9.5	1.4
1400/50	Diesel	27.	8.5	1.9
	Methanol	5.6	2.7	1.4
	Meth.-Cat.[a]	--	--	--
1400/100	Methanol	4.3	2.5	1.4
	Meth-Cat.	--	1.9	0.8
Idle	Diesel	77.	33.	2.5
	Methanol	37.	18.	2.3
	Meth-Cat.	7.7	6.5	1.3
	Meth-Cat. + BP.	12.	4.1	1.3
2200/100	Diesel	--	1.5	1.2
	Methanol	2.4	3.3	1.0
	Meth.-Cat.	--	1.0	0.8
2200/50	Methanol	3.9	4.7	1.2
	Meth + Cat.	--	0.7	0.6
2200/2	Methanol	76.	7.3	0.8
	Meth-Cat.	10.	9.9	1.7

---

[a] Sample void

1. Total Particulate

Total particulate emission rates are given in Table 39 for the various fuel configurations tested under steady-state modal operation. Figure 15 shows the relative total particulate mass rates. Comparison was simplified because both test engines were of similar design and had the same rated speed and power. Particulate emissions from the diesel configuration exceeded those of the alcohol configurations except at the 2 percent load conditions. At the 2 percent load conditions, the methanol and the ethanol+water configurations show significantly higher particulate than either the diesel or the methanol-catalyst-backpressure configurations. The backpressure device was engaged only at idle, and required more diesel pilot injection to maintain idle speed. Idle particulate rate from the diesel engine was greater than for the methanol configuration of the dual-fuel engine.

Although the dual-fuel used only diesel fuel at idle, there are significant differences in the manner in which the diesel fuel is injected. The diesel engine uses a large 4-hole injector mounted in approximately the center of the combustion chamber; whereas the dual-fuel engine uses a similar but smaller injector and injects the pilot diesel fuel against the swirl within the combustion chamber (refer to Section III.A.). These differences in diesel fuel injection between engines may explain the significantly different particulate emission rates observed for the 1400 rpm/2 percent load condition, at which only diesel fuel pilot injection is active. About 81 percent of the fuel consumed by the dual-fuel engine at 2200 rpm/2 percent load consisted of diesel pilot injection. Idle data from the methanol configuration were also used for the ethanol+water configuration, because they are taken to be identical (only pilot injected diesel fuel is used at idle, so idle emissions should be independent of the alcohol used). Relative to the diesel engine, major particulate reductions with both methanol and ethanol+water configurations were noted where substantial amounts of alcohol were substituted for diesel fuel, beyond the 2 percent load conditions.

Catalysts are usually considered a method for reducing emissions but total particulates were substantially increased in the alcohol configurations when the catalyst was used. Addition of the catalyst increased the particulate emissions substantially at the higher load conditions where exhaust heat was sufficient to activate the catalyst. The catalyst reduced particulate emissions at idle and light load conditions where exhaust temperature was relatively low. With low-temperature exhaust from idle and light loads, the catalyst appeared to act as a particulate trap. Above about 25 percent load, catalyst temperatures elevated enough to begin oxidation reactions. At this point, the total particulate emission increased sharply. A significant portion of this particulate matter is made up of sulfate generated by the catalyst. Sulfate will be discussed in the next section.

TABLE 39. PARTICULATE EMISSION SUMMARY FROM MODAL OPERATIONS OF THE VOLVO TEST ENGINES

		Engine/Fuel Configuration			
Condition rpm/load, %	Units	Diesel	Methanol	Methanol -Catalyst	Ethanol + Water
1400/2	mg/m^3 exh.	53.53	116.48	47.10	91.77
	g/hr	19.21	40.54	16.25	32.42
	g/kw-hr	9.63	14.48	5.80	11.58
	g/kg fuel[a]	4.93	9.72	3.66	7.95
1400/50	mg/m^3 exh.	45.67	21.91	48.95	19.62
	g/hr	18.29	9.30	21.08	8.22
	g/kw-hr	0.28	0.14	0.31	0.12
	g/kg fuel[a]	1.22	0.34	0.75	0.31
1400/100	mg/m^3 exh.	134.06	15.61	89.75	22.92
	g/hr	69.87	9.19	52.98	13.30
	g/kw-hr	0.54	0.07	0.39	0.10
	g/kg fuel[a]	2.41	0.15	0.89	0.22
Idle	mg/m^3 exh.	66.92	48.63	16.68[c]	48.63[b]
	g/hr	7.85	5.67	1.84[c]	5.67[b]
	g/kw-hr	--	--	--	--
	g/kg fuel[a]	6.65	4.85	1.52[c]	4.85[b]
2200/100	mg/m^3 exh.	81.56	6.79	72.74	10.25
	g/hr	77.97	6.56	68.96	10.15
	g/kw-hr	0.44	0.04	0.38	0.05
	g/kg fuel[a]	1.78	0.08	0.82	0.11
2200/50	mg/m^3 exh.	103.83	23.30	80.70	34.20
	g/hr	78.25	17.10	58.87	25.27
	g/kw-hr	0.88	0.18	0.63	0.27
	g/kg fuel[a]	3.11	0.38	1.33	0.54
2200/2	mg/m^3 exh.	84.49	117.44	50.90	122.42
	g/hr	49.15	62.72	26.49	67.59
	g/kw-hr	14.49	15.30	6.97	17.79
	g/kg fuel[a]	5.37	7.20	2.61	7.37

---

[a] "Fuel" represents total fuel input to engine and includes water, alcohol, and diesel

[b] These values were duplicated from the methanol configuration since only diesel fuel is used

[c] Particulate data for Methanol-Catalyst-Backpressure were: 16.01 mg/m^3 exh., 1.43 g/hr, 1.18 g/kg fuel[a]

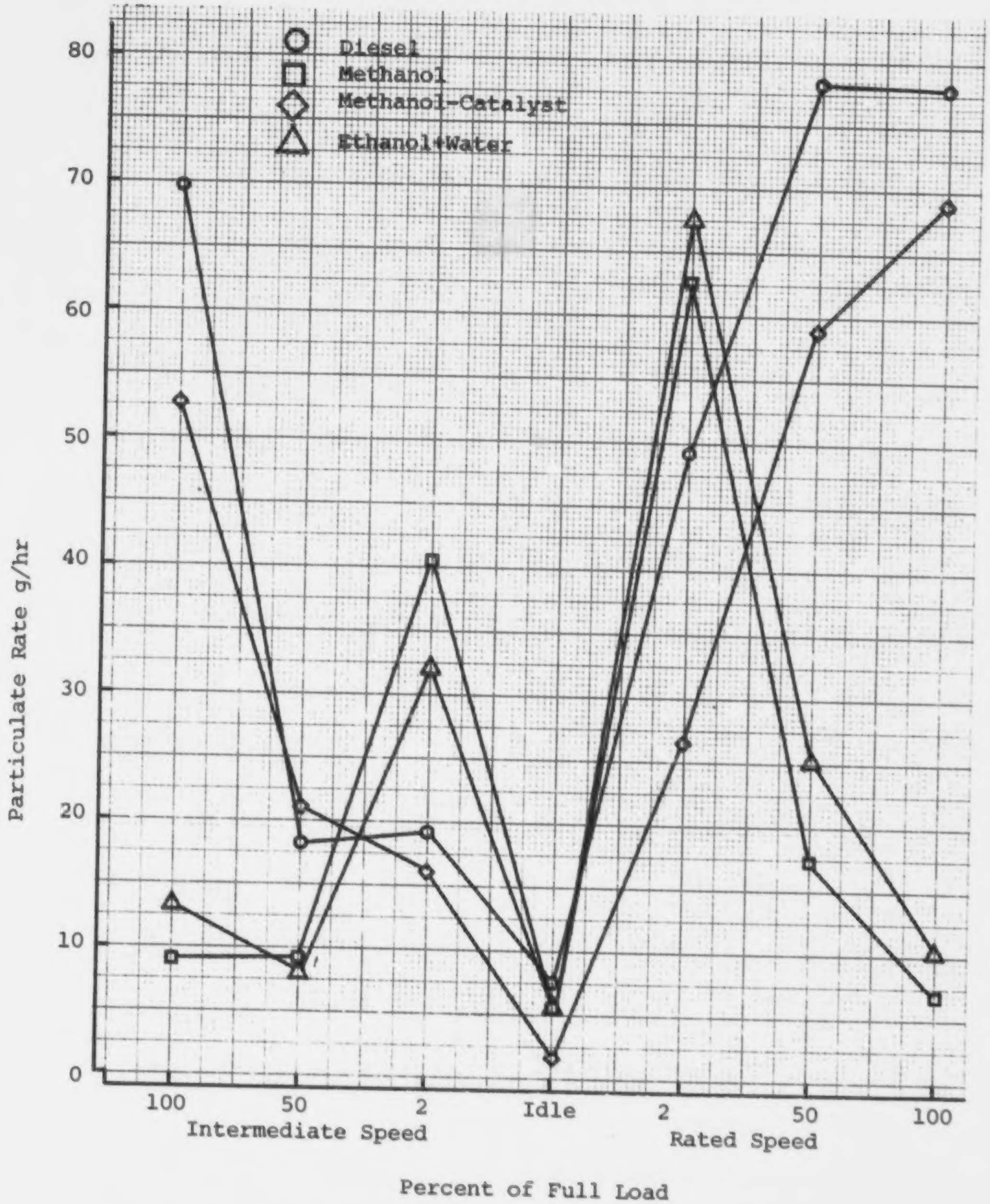

Figure 15. Modal particulate from the Volvo test engines

Particulate rates determined for cold- and hot-start transient cycles and the bus cycle are given in Table 40, along with composite transient results. These particulate emissions were also given along with gaseous emission data in Tables 13 and 14.

TABLE 40. PARTICULATE SUMMARY FROM TRANSIENT OPERATION OF THE VOLVO TEST ENGINES

Test Configuration	Transient Particulate g/kW-hr			
	Cold Start	Hot Start	Composite	Bus Cycle
Diesel	0.80	0.68	0.70	0.82
Methanol	0.36	0.40	0.39	0.60
Methanol-Catalyst	0.26	0.34	0.33	0.22
Methanol-Catalyst-Backpressure	0.28	0.42	0.40	0.24
Ethanol	0.34	0.35	0.35	0.60
Ethanol-Catalyst-Backpressure	0.34	0.39	0.38	0.38

In the diesel configuration, the cold-start runs produced more particulate than the hot-start runs, which seems to be typical of most of the diesel engines tested under the EPA "Baseline" Contract. The dual-fuel engine configurations gave lower particulate for the cold-start than for the hot-start FTP. The catalyst appears to have reduced particulate from the cold-start, but increased particulate from the hot-start. The catalyst reduced particulate from the bus cycle by about half. Considering the modal information, the catalyst may have reduced particulate from the cold-start by acting as a trap at lower exhaust temperatures. Particulate from the hot-start may have increased because the catalyst was warmer, being able to produce sulfate while oxidizing fuel-like constituents which would have condensed as particulate during the cold-start. The reduction of particulate emissions from the bus cycle run with catalyst may be due to the catalyst being able to oxidize a greater mass of organic (fuel-like) particulate matter than it produces as sulfate, or to storage.

Table 41 gives the computed 7-mode composite (based on the 13-mode composite weighting factors) and the transient composite particulate rates on a brake specific and a fuel specific basis. There is very good agreement between the 7-mode and the transient composite for the diesel configuration. The transient composite is somewhat higher than the modal composite in the methanol configuration without aftertreatment, but is substantially lower than the modal composite when the catalyst is used.

TABLE 41. COMPOSITE PARTICULATE RATES FROM MODAL AND TRANSIENT OPERATION OF THE VOLVO TEST ENGINES

Test Configuration	7-Mode Composite		Transient Composite	
	g/kW-hr	g/kg fuel	g/kW-hr	g/kg fuel
Diesel	0.69	2.53	0.70	2.43
Methanol	0.30	0.64	0.39	0.73
Methanol-Catalyst	0.51	1.07	0.33	0.64
Methanol-Catalyst-Backpressure	0.51	1.07	0.40	0.70
Ethanol	- Not Run -		0.35	0.81
Ethanol-Catalyst-Backpressure	- Not Run -		0.30	0.85
Ethanol+Water	0.33	0.67	- Not Run -	

The greater disagreement between the modal composite and the transient composite when the catalyst was used is due to the catalyst's heat sensivity and the load variations among the cycles. The transient cycle consists of mostly light loads, but the 7-mode composite includes substantial operating time at loads of 50 percent or more (56 percent of the 7-mode composite).

2. Smoke

Smoke and particulate emissions are related, smoke level being a measure of the visible portion of particulate matter. Changes in particulate emissions may be indicated by corresponding changes in smoke opacity, if the levels are high enough. Smoke opacity was determined using an end-of stack PHS smokemeter. Table 42 gives a summary of smoke opacity data collected from all six fuel configurations; namely, diesel, methanol, methanol-catalyst, ethanol, ethanol-catalyst, and ethanol+water.

Smoke factors for acceleration, lug, and peak are all well below the 1980 standards, for the dual-fuel engine. In the diesel configuration, there was reasonable agreement with manufacturer's data for the acceleration and peak factors, but the lug factor was much higher than the manufacturer's value of about 7 percent opacity. Examination of the diesel smoke chart indicated that smoke opacity increased sharply in the last four seconds of the lug procedure run under automatic dynamometer/engine control. The lug factor should be about 7-9 percent opacity on the basis of the power curve smoke, which also simulates a maximum rack lug-down from rated speed.

TABLE 42. SUMMARY OF SMOKE OPACITY FROM THE VOLVO TEST ENGINES

Federal Transient Smoke Cycle Opacity[a]

Test Configuration	Smoke Opacity, %		
	Accel.	Lug	Peak
Diesel	15.3	15.0[b]	32.6
Methanol	6.0	0.8	23.3
Methanol - Catalyst	2.6	0.7	6.9
Ethanol	5.7	1.4	10.9
Ethanol - Catalyst	3.6	2.7	4.7
Ethanol + Water		-- NOT RUN --	
1980 Standard	20.0	15.0	50.0

Steady-State Smoke Opacity

13-Mode FTP			Smoke Opacity, %					
Mode	RPM	Power, %	Diesel	Methanol	Meth.-Cat.	Ethanol	Eth.-Cat.	Eth. + Water
1	500	Idle	0.4	0.1	0.1	0.1	0.1	0.6
2	1400	2	0.4	0.6	0.2	0.4	0.2	1.1
3	1400	25	0.8	0.9	0.4	1.1	0.1	1.2
4	1400	50	1.2	1.2	1.0	1.8	1.0	1.4
5	1400	75	2.0	1.1	1.4	2.4	1.7	3.0
6	1400	100	6.0	0.9	1.3	2.3	1.4	3.5
7	500	Idle	0.5	0.1	0.6	0.2	0.1	0.4
8	2200	100	3.5	0.7	0.7	1.0	0.9	0.9
9	2200	75	5.0	0.8	0.5	0.7	0.8	1.0
10	2200	50	5.3	1.1	0.8	1.4	1.2	1.0
11	2200	25	3.1	2.0	1.9	3.0	2.2	1.1
12	2200	2	1.4	2.0	2.1	3.1	2.4	0.9
13	500	Idle	0.2	0.1	0.3	0.2	0.1	0.2

Power Curve Smoke Opacity

Power Curve Smoke Opacity						
RPM	Diesel	Methanol	Meth.-Cat.	Ethanol	Eth.-Cat.	Eth. + Water
2200	4.0	0.8	0.8	0.6	1.0	0.9
2000	4.0	0.8	0.9	0.4	0.8	0.8
1800	4.0	0.6	1.3	0.5	0.8	1.5
1600	5.2	0.7	2.3	1.0	1.0	2.0
1400	7.0	1.0	2.2	2.0	2.3	4.0
1300	9.0	1.2	1.4	2.4	2.6	2.5

---

[a] These values were based on a single run of the FTP smoke test

[b] This value may be in error and is likely to be 7 - 9 percent opacity on the basis of power curve data

The catalyst reduced accel and peak factors on both methanol and ethanol, but the lug factor appeared to increase for the ethanol-catalyst configuration. Modal and power curve smoke were all very low for the dual-fuel engine. Most of the smoke opacities listed are considered hardly visible usually below five percent opacity.

3. Sulfate

Sulfate was determined from samples of total particulate collected on 47 mm Fluoropore filter media, and processed by the BCA method. Table 43 summarizes the sulfate results from 7 modes of steady-state operation taken over four test configurations. In order to visualize the trends, Figure 16 shows the relative sulfate mass rates. Taking the diesel configuration as base, the methanol and ethanol+water configurations had very low sulfate rates, especially above the 2 percent load condition. These two alcohol configurations showed almost identical sulfate results. Since the sulfate originates from the sulfur in the fuel, less diesel fuel consumed by the dual-fuel engine meant less sulfur was available to be converted to sulfate. Sulfate rates have been expressed in terms of "mg/kg C fuel" and "mg/kg D fuel." The "C" represents fuel as measured on the combined basis of diesel fuel used for pilot injection and alcohol fuel used for combustion. The "D" represents only the diesel fuel used. The percent of fuel sulfur converted to sulfate was computed on the basis of the diesel fuel used.

Probably the most notable sulfate trend was the dramatic increase in sulfate as a result of the catalyst. Tremendous increases in sulfate were noted for the high power modes, where exhaust heat insured that the catalyst was active. The fuel sulfur conversion reached 97 percent at the maximum power condition. Since the sulfate is collected as part of the total particulates, the sulfate measured at maximum power in the methanol-catalyst-backpressure configuration accounts for 83 percent of the total particulate. The catalyst appeared to reduce sulfate emissions during idle and the 2 percent conditions, possibly due to a sulfate storage phenomenon.(16)

Sulfate results from transient operation are given in Table 44. The methanol and ethanol configurations emitted similar levels of sulfate, which were about half that of the diesel engine. Application of the catalyst to the alcohol configurations increased the transient sulfate levels substantially. The transient composite sulfate level from the methanol-catalyst configuration increased sharply again when retested with the backpressure device. Use of the backpressure device required more pilot injection of diesel fuel. Transient composite sulfate levels from the methanol-catalyst-backpressure configuration were about 30 percent higher than the ethanol-catalyst-backpressure configuration. This relatively large difference may be attributed to a slightly greater catalyst activity when methanol is used.

TABLE 43 . SULFATE EMISSIONS SUMMARY FROM MODAL OPERATION OF THE VOLVO TEST ENGINES

Condition rpm/load, %	Test Configuration	Sulfate Emission Rates					
		mg/m^3 Exhaust	mg/hr	mg/kw-hr	mg/kg C Fuel[b]	mg/kg D Fuel[c]	$SO_4^=$ as % of Fuel S[a]
1400/2	Diesel	3.0	1100	410	280	280	3.9
	Methanol	3.1	1100	390	260	260	3.6
	Meth.-Cat.	1.4	510	180	110	110	1.5
	Eth. + Water	3.7	1300	460	330	330	4.6
1400/50	Diesel	5.4	2100	33	140	140	2.0
	Methanol	1.2	520	7.7	19	19	1.2
	Meth.-Cat.	20.	8400	120	300	1400	19.
	Eth. + Water	1.6	690	10	25	100	1.4
1400/100	Diesel	5.6	2900	23	100	100	1.4
	Methanol	1.4	850	6.2	14	140	1.9
	Meth.-Cat.	41.	17000	120	290	2700	37.
	Eth. + Water	1.4	790	5.8	12	120	1.7
Idle	Diesel	4.7	550	--	470	470	6.5
	Methanol	3.1	370	--	320	320	4.4
	Meth.-Cat.[d]	0.84	77	--	44	44	0.61
	Eth. + Water[e]	3.1	370	--	320	320	4.4
2200/100	Diesel	7.4	7100	40	160	160	2.2
	Methanol	1.6	1600	8.7	19	200	2.8
	Meth.-Cat.	59.	57000	320	680	7000	97.
	Eth. + Water	1.7	1700	8.8	18	200	2.8
2200/50	Diesel	5.2	3900	44	160	160	2.2
	Methanol	1.2	860	9.2	19	110	1.5
	Meth.-Cat.	34.	24000	260	540	3200	44.
	Eth. + Water	1.6	1200	12	23	150	2.1
2200/2	Diesel	5.3	3100	900	330	330	4.6
	Methanol	3.4	1800	440	210	240	3.3
	Meth.-Cat.	1.5	780	210	77	110	1.5
	Eth. + Water	4.3	2400	630	250	310	4.3

---

[a] Percent of fuel sulfur converted to sulfate was computed on basis of the diesel fuel alone. The diesel fuel had a reported sulfur content of 0.24 percent by weight.

[b] mg/kg C fuel represents sulfate on a combined fuel basis

[c] mg/kg D fuel represents sulfate on the basis of the diesel portion of the combined fuel

[d] Data from idle with backpressure device were 0.84 mg/m^3, 77 mg/hr, 44 mg/kg D fuel[c], and 0.61 percent fuel sulfur conversion

[e] These data duplicated from idle condition of methanol configuration

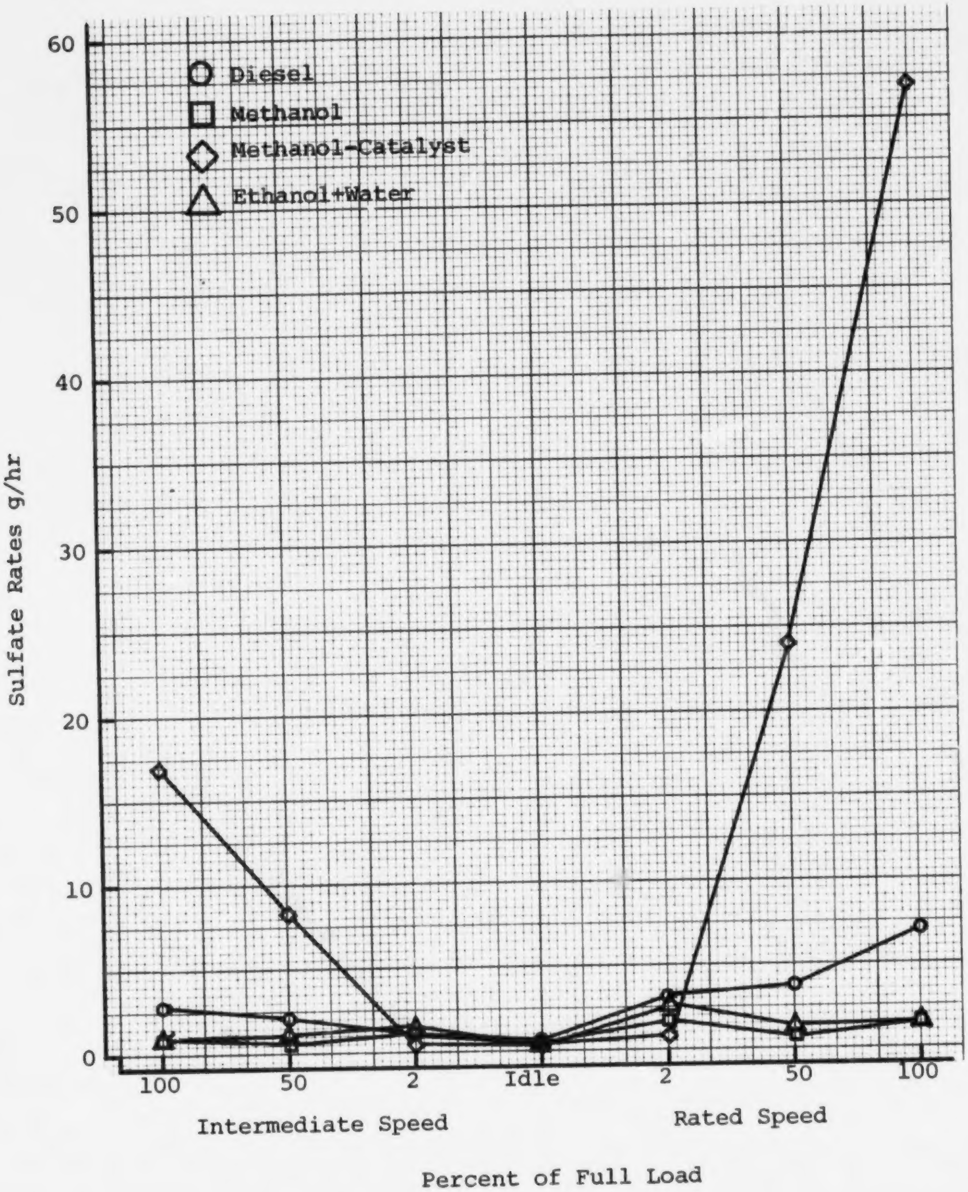

Figure 16. Modal sulfate rates from the Volvo test engines

TABLE 44 . SULFATE EMISSION SUMMARY FROM TRANSIENT FTP OPERATION FROM THE VOLVO TEST ENGINES

Test Config.	Transient Cycle	Sulfate Rate mg/test	mg/kw-hr	C fuel[b]	D fuel[c]	$SO_4^=$ as % of Fuel S[a]
Diesel	Cold	520	51	170	170	2.3
	Hot	390	36	130	130	1.8
	Composite	410	38	140	140	1.9
Methanol	Cold	170	14	27	170	2.3
	Hot	170	16	29	160	2.3
	Composite	170	16	29	160	2.3
Methanol -Catalyst	Cold	670	60	110	650	9.1
	Hot	900	80	160	870	12.
	Composite	870	77	150	840	12.
Methanol -Cat.-Bp.	Cold	710	67	110	690	9.6
	Hot	1500	130	240	1500	20.
	Composite	1400	120	220	1400	19.
Ethanol	Cold	170	15	31	160	2.3
	Hot	160	14	31	150	2.1
	Composite	160	14	31	150	2.1
Ethanol -Cat.-Bp.	Cold	930	83	180	900	13.
	Hot	1000	90	200	1000	14.
	Composite	990	89	200	990	14.

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[a] Average diesel fuel consumption was 1.02 kg/transient cycle for dual fuel applications. The fuel had a reported sulfur content of 0.24 percent by weight

[b] mg/kg C fuel represents sulfate on a combined fuel basis

[c] mg/kg D fuel represents sulfate on a diesel fuel basis only

Results from 7-mode composite and transient composites are given in Table 45. In non-catalyst configurations, results from 7-mode composites and transient composites were in agreement. When the catalyst was used, the 7-mode composite sulfate level was higher than the transient composite level due to the higher exhaust temperatures and higher loads run during the 7-mode testing. For the methanol configuration, the 7-mode brake specific sulfate increased from 14 to 220 mg/kW-hr with the addition of the catalyst. This 0.2 g/kW-hr increase in brake specific sulfate probably accounts for the increase in 7-mode brake specific total particulate from 0.30 to 0.51 g/kW-hr.

TABLE 45. COMPOSITE SULFATE RATES FROM MODAL AND TRANSIENT OPERATION OF THE VOLVO TEST ENGINES

Test Configuration	7-Mode Composite		Transient Composite	
	mg/kW-hr	mg/kg C fuel[a]	mg/kW-hr	mg/kg C fuel[a]
Diesel	145	160	38	140
Methanol	14	30	16	29
Meth.-Cat.	220	470	77	150
Meth.-Cat.-Bp.	220	470	120	220
Ethanol	-- NOT RUN --		14	31
Eth.-Cat.-Bp.	-- NOT RUN --		89	200
Eth. + Water	17	35	-- NOT RUN --	

---

[a] mg/kg C fuel represents sulfate on the basis of total "combined" fuel input

4. Elemental Composition

Elemental analysis of the total particulate required two particulate samples. The carbon and hydrogen content of the total particulate were determined from particulate samples collected on glass fiber filter media by oxidation techniques. Sulfur and metal content were determined from particulate samples collected on Teflon membrane filter media (Fluoropore) using X-ray fluorescence techniques. The carbon and hydrogen were determined by Galbraith Laboratories, and the sulfur and metals were determined by EPA-RTP.

Tables 46 and 47 give the results from elemental analysis of steady-state and transient particulate samples. The results are presented as

TABLE 46. SUMMARY OF ELEMENTAL ANALYSIS OF TOTAL PARTICULATE FROM MODAL OPERATION OF THE VOLVO TEST ENGINES

Condition rpm/load, %	Test Configuration	Element, Percent by Weight of "Total Particulate"											Total Metal, %
		C	H	"S"	Ca	Na	Mg	Fe	Zn	P	Al	Ti	
1400/2	Diesel	86.8	10.4	1.04	0.09	b	b	b	a	0.05	b	b	0.83
	Methanol	75.9	10.5	0.55	0.08	b	a	a	a	a	a	a	0.08
	Meth.-Cat.	75.9	10.4	0.72	0.10	b	0.02	b	a	a	a	a	0.12
	Eth.+Water	71.0	9.6	0.62	0.07	b	b	b	a	0.03	b	b	0.10
1400/50	Diesel	66.8	7.9	2.98	0.20	b	a	0.15	0.16	0.07	b	b	0.63
	Methanol	47.1	4.5	2.92	0.35	b	a	a	0.29	a	b	b	0.64
	Meth.-Cat.	18.8	2.3	8.75	0.15	b	0.01	b	a	a	0.85	b	0.74
	Eth.+Water	46.5	4.5	2.51	0.70	b	a	b	a	a	b	a	0.70
1400/100	Diesel	91.3	0.9	1.26	0.08	b	b	a	a	a	a	b	0.43
	Methanol	77.2	1.9	2.53	0.52	0.51	0.03	1.61	a	b	b	a	2.67
	Meth.-Cat.	10.0	1.2	9.68	0.12	b	a	0.11	a	a	0.65	a	0.88
	Eth.+Water	54.3	1.2	1.54	0.74	b	a	a	b	a	b	a	0.74
Idle	Diesel	59.1	6.4	1.15	0.27	b	b	b	b	a	b	b	1.10
	Methanol	65.8	8.7	1.32	0.12	b	0.02	b	0.14	a	b	b	0.28
	Meth.-Cat.	40.4	5.8	1.34	a	b	b	a	a	b	b	b	--
	Meth.-Cat.Bp	43.5	6.2	1.28	1.56	a	b	b	b	b	a	a	1.56
	Eth.+Water[d]	65.8	8.7	1.32	0.12	b	0.02	b	0.14	a	b	b	0.28
2200/100	Diesel	63.6	1.7	2.73	0.40	b	0.02	0.32	0.30	0.14	0.04	b	1.46
	Methanol	77.4	6.2	7.04	3.16	a	0.11	1.58	1.63	0.85	b	a	7.33
	Meth.-Cat.	2.4	1.7	10.91	0.18	a	0.01	0.19	0.09	0.06	0.36	0.01	0.90
	Eth.+Water	48.9	2.5	5.26	2.82	b	a	0.59	1.25	0.76	0.38	b	5.80
2200/50	Diesel	82.7	2.5	1.76	0.11	a	b	a	0.11	0.04	0.01	b	0.30
	Methanol	69.7	3.2	1.75	0.27	a	a	a	0.20	0.10	b	a	0.57
	Meth.-Cat.	19.0	1.5	8.38	0.06	0.12	0.01	0.08	a	a	0.34	a	0.61
	Eth.+Water	68.6	2.7	0.79	0.17	0.30	b	b	b	a	b	b	0.47
2200/2	Diesel	71.2	8.3	0.65	0.04	b	b	b	b	a	b	b	0.19
	Methanol	69.4	6.5	0.53	b	b	b	b	a	b	b	b	--
	Meth.-Cat.	73.9	7.1	0.62	a	b	a	b	a	b	0.08	b	0.08
	Eth.+Water	70.0	8.5	0.93	0.43	a	a	b	a	0.09	b	0.11	0.54

---

[a] Element was detected but was below the level of quantitation
[b] Element was not detected
[c] Total metals include all elements listed except C, H, and S
[d] Data duplicated from methanol configuration

TABLE 47. SUMMARY OF ELEMENTAL ANALYSIS OF TOTAL PARTICULATE FROM TRANSIENT OPERATION OF THE VOLVO TEST ENGINES

Test Configuration	Trans. Cycle	Element Percent by Weight of Total Particulate						Total[c] Metals %
		C	H	"S"	Ca	P	Al	
Diesel	Cold Start	70.	4.7	2.0	0.27	0.10	0.10[a]	0.38
	Hot Start	70.	4.4	1.7	0.19	0.08	b	0.27
Methanol	Cold Start	44.	5.6	1.4	0.42	0.18	0.05[a]	0.65
	Hot Start	52.	7.0	1.3	0.34	0.15	0.05[a]	0.54
Methanol -Catalyst	Cold Start	24.	3.6	7.8	0.44	0.14	6.8	7.38
	Hot Start	25.	3.2	6.2	0.37	0.14	8.9	9.41
Methanol -Cat.-Bp.	Cold Start	31.	3.7	5.3	0.31	0.11[a]	2.3	2.72
	Hot Start	27.	3.4	9.2	0.15[a]	----[b]	2.1	2.25
Ethanol	Cold Start	63.	6.3	0.80	0.38	0.14	0.11	0.62
	Hot Start	57.	5.6	0.75	0.17[a]	----[b]	0.06[a]	0.23
Ethanol -Catalyst	Cold Start	43.	3.8	5.6	0.11[a]	----[b]	2.2	2.31
	Hot Start	35.	2.7	7.2	0.11[a]	----[b]	2.2	2.31

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[a] These values approach the limits of quantitative analysis by X-ray technique
[b] Presence of this element was below the limit of detectability
[c] "Total Metals" consists only of Ca, P, and Al

percent of each element in the total particulate sample analyzed. The total particulate sample varies with the filter type used.(17) Total particulate is defined in terms of Teflon-coated glass fiber filter media (Pallflex TA60A20, for this program).(5) Glass fiber filters tended to overestimate the total particulate, while the Teflon membrane filter results correlated well with the Teflon-coated glass fiber values.(18)

Of all the elements determined, carbon and hydrogen generally make up the bulk of the total particulate followed by sulfur and oxygen. In addition, trace amounts of a wide variety of elements which range from sodium (23 atomic weight units) to barium (137 atomic weight units). Of the trace elements, calcium, phosphorus, iron, and aluminum were most commonly found in detectable quantities. Carbon and hydrogen content were very similar among the various configurations at light load and at idle, which may be expected since only diesel fuel was consumed at light loads. Methanol and ethanol+water configurations were similar, with lower carbon content than for the diesel configuration at the 50 percent load conditions. Carbon content from full load conditions with methanol alone was higher than with ethanol+water. The catalyst was very effective in reducing carbon content of the particulate from the higher-powered modes of operation, where catalyst heat was sufficient for oxidation to take place. Sulfur content, noted as sulfate earlier, was substantially increased at these same high-heat power modes with the catalyst, otherwise sulfur content of the total particulate was relatively low. The sulfur content was relatively high during the maximum power modes run with methanol and ethanol+water. Similarly, the total of trace materials was relatively high for maximum power operation. It is interesting that a variety of trace elements was detected for both the maximum torque and the maximum power conditions where alcohol substitution for diesel fuel was greatest. Many of the trace metals detected by X-ray fluorescence are assumed to have originated from the fuel refining process, engine oil, and engine wear.

In comparing results from the transient testing, carbon and hydrogen content appear to be independent of cold or hot start-up. Carbon content was lower for the methanol and ethanol configurations. The catalyst reduced carbon content, but not to the extent noted from the modal information. Use of the catalyst significantly increased the aluminum and sulfur levels in the particulate. The use of the backpressure device in conjunction with the catalyst appeared to coincide with lower aluminum content. It is assumed that the aluminum may have originated from the catalyst.

5. Particle Size Distribution

Particle sizing by the Sierra Model 220 cascade impactor was used to obtain particle size distributions from 7 modes of steady-state operation and from transient cycle operation of the dual-fuel engine. The size distribution plots are influenced strongly by the back-up filter, which generally accounted for approximately 50 percent or more of the particulate collected. Problems with the back-up filter sticking to its O-ring seal, and with determining the weight gains of the individual impactor stages were causes for inaccuracies. In order to improve accuracy, the impactor set was operated during several transient cycles, or for one hour of steady-state operation. Due to the level of effort required and the quality of information obtained, particle sizing was limited to the methanol and the methanol-catalyst configurations for modal testing, and to transient testing of the methanol, methanol-catalyst, ethanol, and ethanol-catalyst configurations.

Particle size distributions from modal operation are given in Figures 17 and 18 for the methanol and the methanol-catalyst configurations. With the catalyst, the size distribution shifted to larger particles at idle, but shifted toward smaller particles at the higher power modes. The "averages" of the particle size distributions for both configurations are given in Figure 19. The average plot for the methanol configuration included six modes of operation (2200 rpm/2 percent load condition was void). The average plot for the methanol-catalyst configuration included seven modes of operation (idle data with and without the back-pressure device were averaged together and used as one mode). The average particle size distributions indicated that more of the particles tended to be smaller when the catalyst was used. This effect may be due to the increased presence of sulfate particles as a result of the catalyst.

Particle size distributions from transient operation are given in Figure 20. In the methanol and ethanol fuel configurations, about 70 percent of the particles were less than 0.11 micron ECD (Effective Cutoff Diameter). Application of the catalyst appears to have reduced the percentage of particles under 0.11 µm diameter to about 50 percent. It is possible that by eliminating some of the fine aerosols associated with unburned fuel in transient operation, the catalyst eliminates a portion of the smaller particles, which shifts the distribution plot to the left. This process would lead to comparative preponderance of larger particles from the catalyst-equipped configurations. This trend is just opposite of that shown for steady-state operation. The difference may be due to limited sulfate formation in the catalyst during the transient testing, whereas significant sulfate was emitted during high-powered steady-state operation. In addition, sulfate storage and purge may also occur in the catalyst during transient operation. Overall, the particle size distributions from the alcohol-fueled configuration were similar to those commonly reported for diesel engine particulate.(19)

6. Soluble Organic Fraction

The soluble organic fraction (SOF) of the total particulate was obtained from particulate samples collected on 20x20 inch Pallflex filters with soxhlet extraction procedures using methylene chloride. The SOF has been reported as a percentage of the total particulate, and is referred to as percent solubles. This result gives an indication as to the

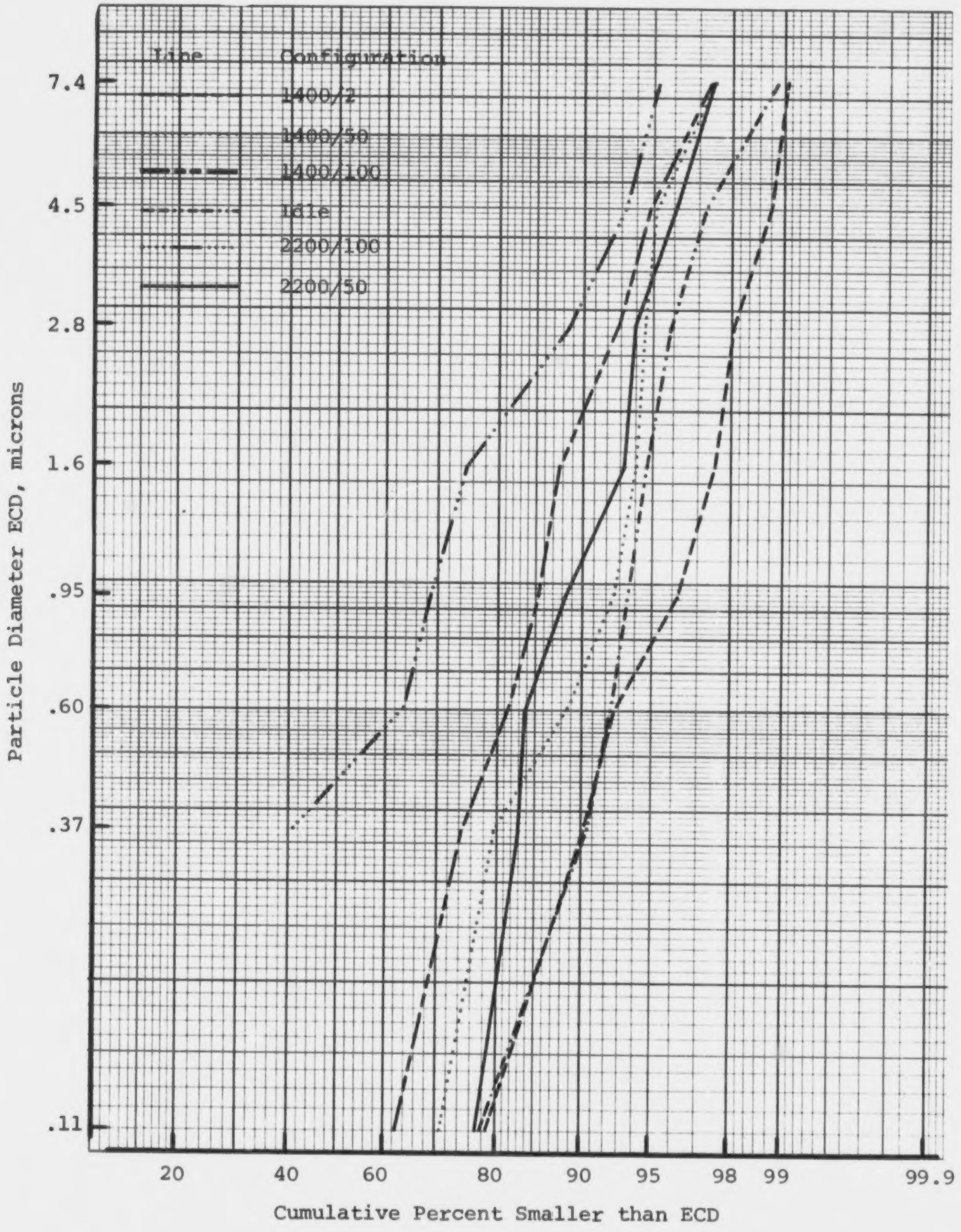

Figure 17. Particle size distribution from modal operation of the Volvo TD-100A dual-fuel engine on methanol

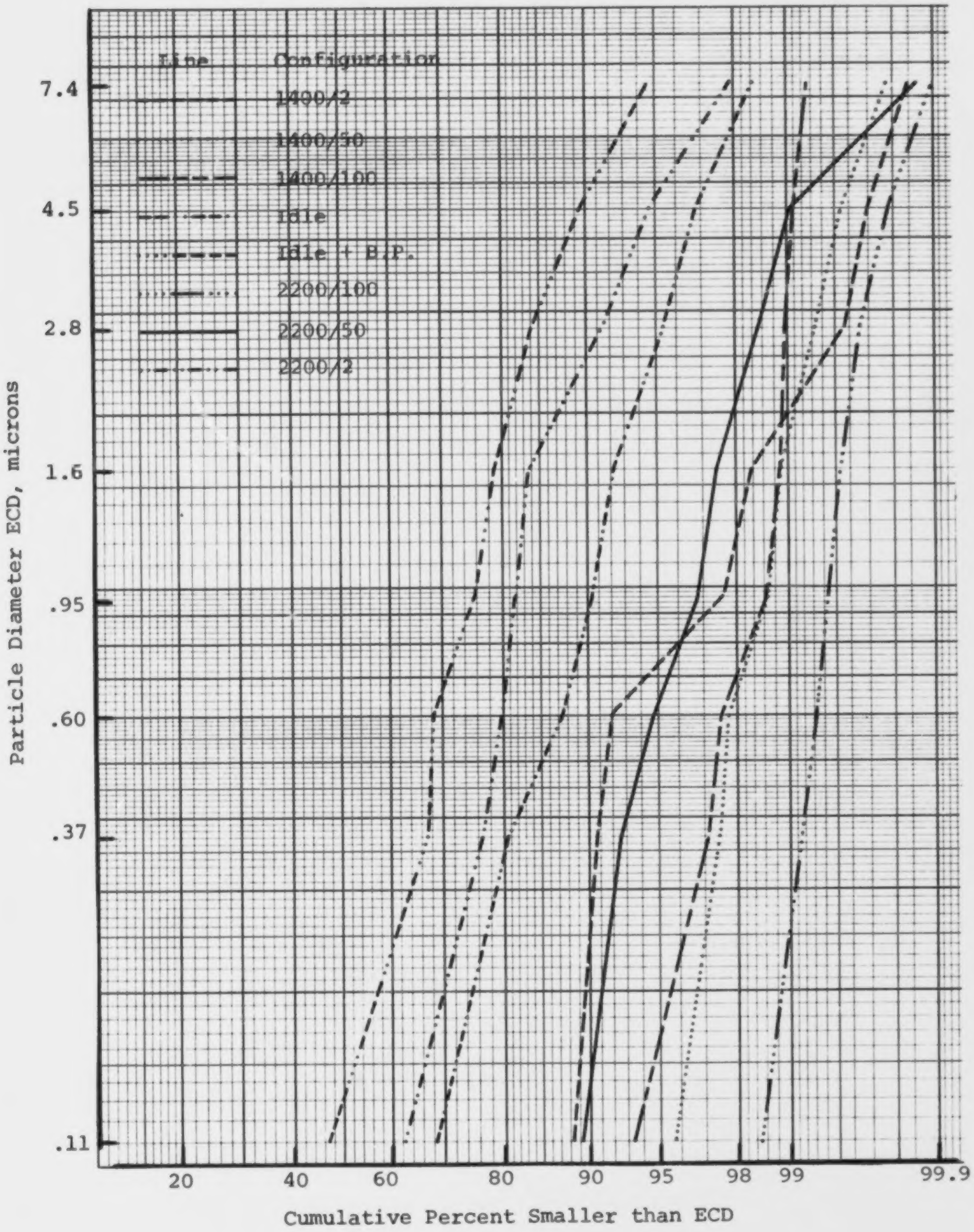

Figure 18. Particle size distribution from modal operation of the Volvo TD-100A dual-duel engine with methanol and catalyst

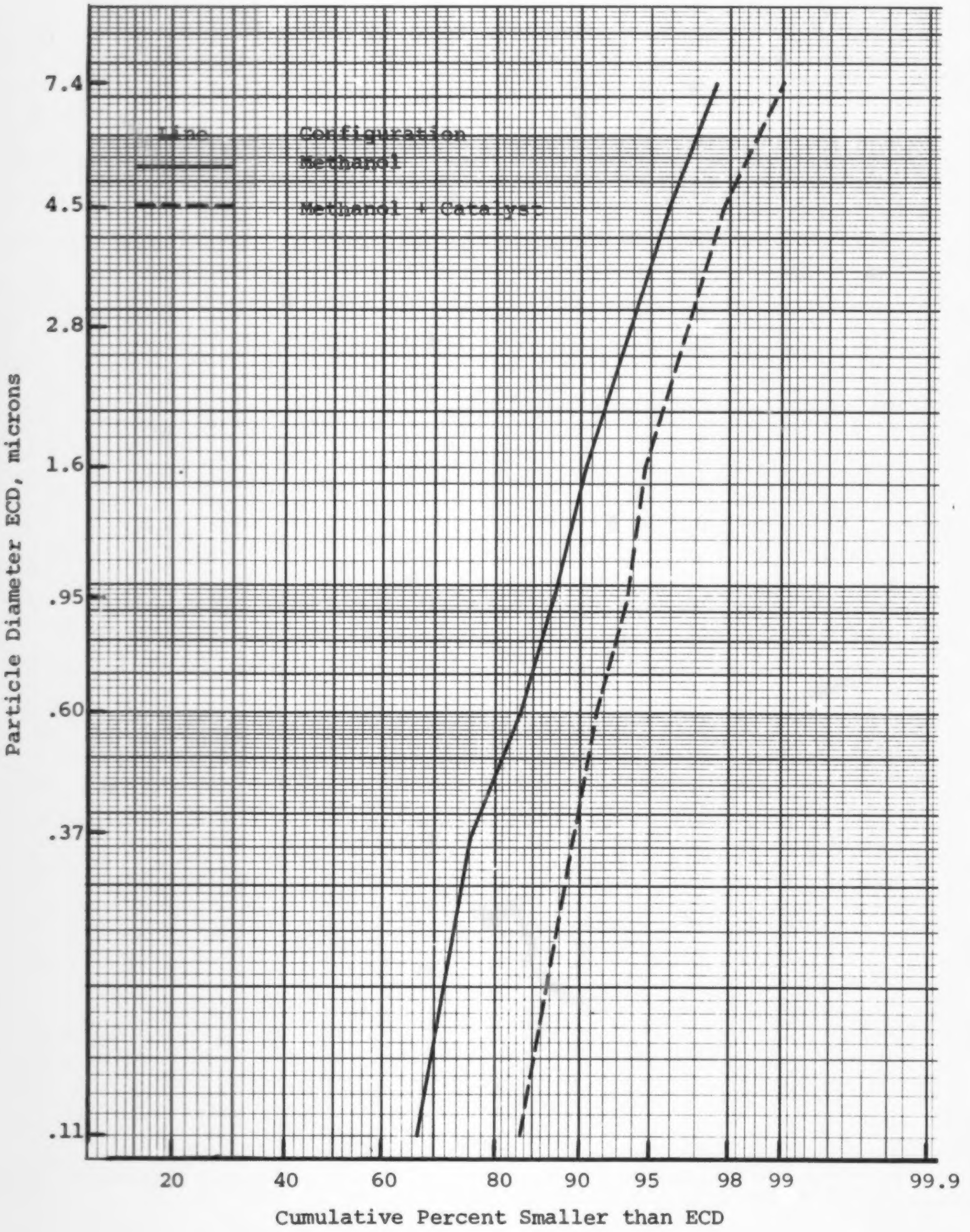

Figure 19. Average of particle size distribution from modal operation of the Volvo TD-100A dual-fuel engine on methanol and methanol with catalyst

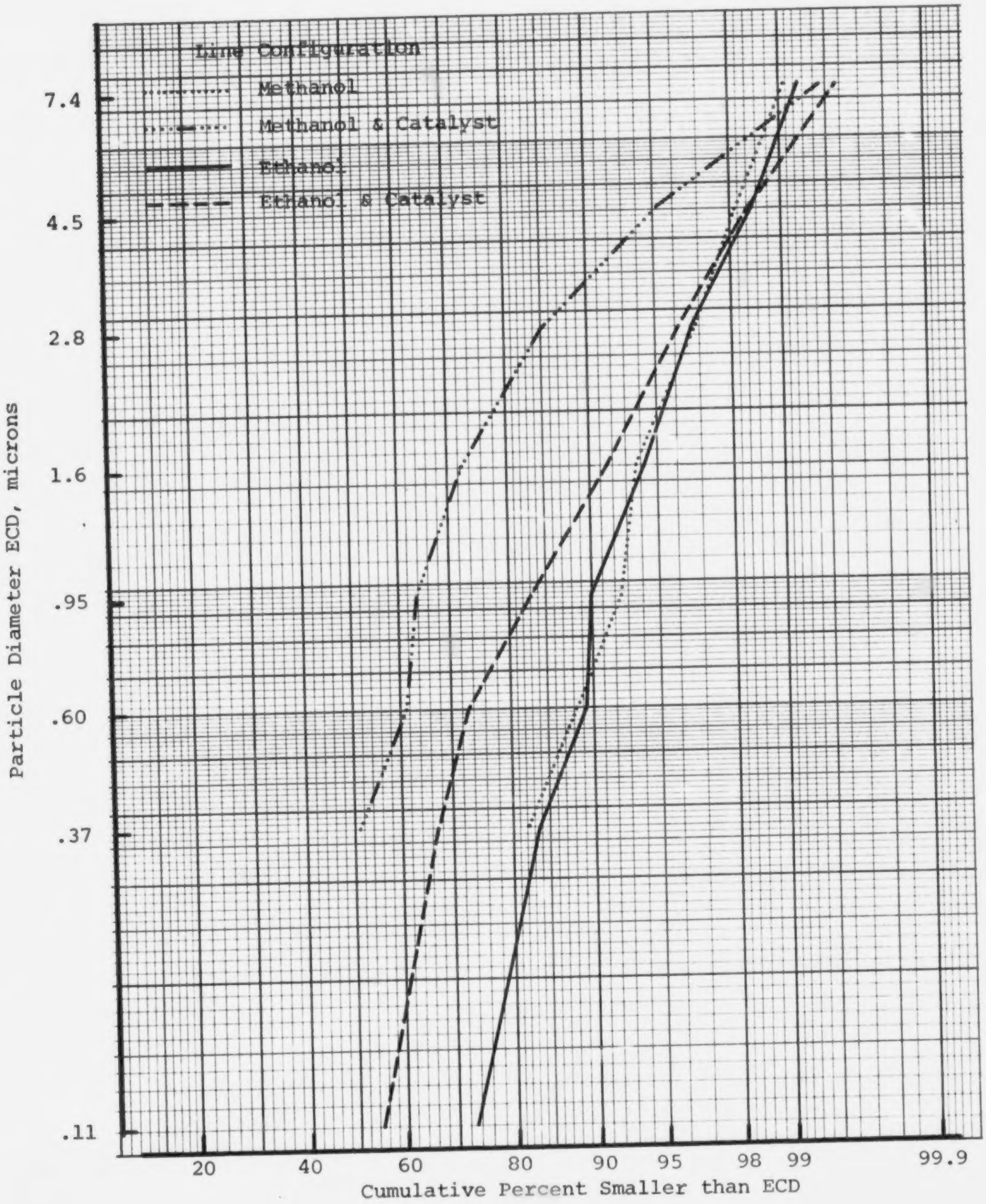

Figure 20. Particle size distribution from transient operation of the Volvo TD-100A dual-fuel engine

nature of the total particulate matter, but it makes it difficult to compare SOF emission rates of the various test configurations. Table 48 summarizes both the SOF mass emission rates and percent solubles from modal operation, and Table 49 summarizes the results from transient operation. Composite values were computed, and they are also given in the tables.

TABLE 48. SUMMARY OF SOLUBLE ORGANIC FRACTION FROM MODAL OPERATION OF THE VOLVO TEST ENGINES

Condition rpm/load, %	Percent Solubles in Total Particulate[a] and (Soluble Particulate Rate (g/hr)) Diesel	Methanol	Meth.-Cat.	Eth. + Water
1400/2	90 (17.)	91 (37.)	93 (15.)	97 (31.)
1400/50	54 (9.9)	34 (3.2)	5.5 (1.2)	40 (3.3)
1400/100	6.8 (4.8)	6.2 (0.6)	1.2 (0.6)	23 (3.1)
Idle	81 (6.4)	81 (4.6)	66[b] (1.2)	81 (4.6)
2200/100	9.3 (7.3)	21 (1.4)	3.3 (2.3)	15 (1.5)
2200/50	9.7 (7.6)	25 (4.4)	3.1 (1.8)	19 (4.8)
2200/2	87 (43.)	83 (52.)	57 (15.)	73 (49.)
7-mode Composite	0.196 g/kW-hr	0.201 g/kW-hr	0.072 g/kW-hr	0.191 g/kW-hr

TABLE 49. SUMMARY OF SOLUBLE ORGANIC FRACTION FROM TRANSIENT OPERATION OF THE VOLVO TEST ENGINES

Test Configuration	Percent Solubles in Total Particulate[a] and (Soluble Particulate Ratio (g/kW-hr)) Cold-Start	Hot-Start	Calc. Composite	Bus
Diesel	35 (.28)	31 (.21)	32 (.22)	39 (.32)
Methanol	62 (.22)	75 (.30)	73 (.29)	76 (.46)
Meth.-Cat.	19 (.05)	15 (.051)	16 (.05)	45 (.10)
Ethanol	48 (.16)	53 (.19)	53 (.19)	65 (.39)
Eth.-Cat.	16 (.05)	10 (.04)	11 (.04)	32 (.12)

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[a] Particulate samples collected on 20X20 inch Pallflex filter media and extracted using methylene chloride

[b] Idle solubles with backpressure device were 16 percent and (0.23 g/hr)

The percent solubles from modal operation of the diesel engine were typical; namely, a relatively high percentage of organic material at low power modes and idle, decreasing as the load was increased. The methanol and the ethanol+water configurations also showed the same trends in regard to the percent solubles, but differed considerably in SOF emission rate. The dual-fuel engine produced less organic solubles than the diesel at idle, but more at the 2 percent load conditions. As mentioned before, this effect may be due to differences in diesel fuel injection geometry between the diesel engine and the dual-fuel engine. The SOF emission rates were similar for both the methanol and ethanol+water configurations, except for the maximum torque condition.

The catalyst reduced SOF modal emission rates in all cases except the maximum torque and the maximum power conditions. The catalyst was especially effective in reducing SOF emissions during idle and the 2 percent load conditions where exhaust temperature is relatively low, perhaps acting as a trap. Use of the backpressure device at idle reduced the SOF emissions even further. The 7-mode composites of the solubles were about the same except for the methanol-catalyst configuration, which showed significant reductions of SOF emissions from the light loads and idle. Although the 7-mode composite SOF values of the diesel engine and the methanol configuration are similar, their SOF emissions for individual modes were very different.

The organic solubles were higher from the cold-start transient than for the hot-start transient in the diesel configuration. This result seems logical, since more unburned diesel fuel-like material would be emitted from a cold engine than from a hot engine; and this material would be collected as total particulates and later be extracted as organic solubles. The SOF emission rates from the methanol and ethanol configurations were lower for the cold-start than for the hot-start, just the opposite of the diesel engine. If it is assumed that the cold dual-fuel engine emits unburned alcohol-like material, then it is possible that it may be lost in the extraction process by evaporation because of its low boiling point. No difference was noted in the SOF emissions between cold-start and hot-start transients with the catalyst. Although the catalyst is a temperature-sensitive device, the significant reductions noted in the SOF emission rates may be the result of the catalyst's ability to act as a trap.

The transient composite SOF emission was highest for the methanol configuration, followed by the diesel and the ethanol configurations. The catalyst reduced the SOF emission by 80 percent in both alcohol fueled configurations. Transient composite SOF emissions were higher from the methanol configuration than from the ethanol configuration, which may be due to different heats of vaporization. The methanol has a higher heat of vaporization, which may have more of a quenching effect on the diesel pilot fuel than does the ethanol. The bus cycle showed the same trends as noted for the transient composite, but with higher overall SOF emission rates. Characterization of the soluble organic fraction is of special interest because it contains a variety of organic compounds which are created through diesel combustion.

a. Elemental Composition

Organic solubles from cold- and hot-start transient operation of the diesel engine and the dual-fuel engine in the methanol and the methanol-catalyst configurations were analyzed for carbon, hydrogen, nitrogen, and sulfur content. Table 50 lists the elements as a percent of the soluble organic fraction. Overall, there was no appreciable difference between the three configurations with respect to carbon and hydrogen content. The catalyst appears to have increased the nitrogen content and decreased the sulfur content of the SOF relative to the diesel and methanol configurations.

TABLE 50. ELEMENTAL COMPOSITION OF SOLUBLE ORGANIC FRACTION FROM TRANSIENT OPERATION OF THE VOLVO TEST ENGINES

Test Configuration	Test Cycle	SOF g/kW-hr	Element, Percent of SOF C	H	N	S
Diesel	Cold	0.28	76.7	9.6	0.47	0.73
	Hot	0.21	77.1	9.9	0.37	0.77
Methanol	Cold	0.22	84.1	13.1	0.29	0.72
	Hot	0.30	84.5	12.9	0.35	0.50
Methanol -Catalyst	Cold	0.05	77.9	10.6	0.72	0.50
	Hot	0.06	80.0	11.2	0.75	0.60

b. Boiling Point Distribution

The organic soluble fraction resembles a very heavy oil or a varnish. A high-temperature GC-simulated boiling point distribution with internal standard (C_9-C_{11}) was conducted on SOF from cold and hot transient operation of the diesel engine, and from the dual-fuel engine in the methanol and the mathanol-catalyst configurations. The boiling point distribution was determined from gas chromatographic output normally used with petroleum oil or fuel samples. The numerical results of these analyses are presented in Table 51. All samples showed relatively high levels of "residue," that is about 34 percent of the SOF sample submitted could not be volatilized below 606°C, which was the maximum column equivalent temperature reached during the procedure used. Extracts from the diesel hot-start and the methanol hot-start were very similar. All the boiling point distributions appeared to be similar up to the 40 percent point. The catalyst seems to have reduced some of the middle weight paraffins, in that the 60 percent point is 571°C instead of 518°C for the methanol case.

TABLE 51. BOILING POINT DISTRIBUTION OF SOLUBLE ORGANIC FRACTION FROM TRANSIENT OPERATION OF THE VOLVO TEST ENGINES

Distillation Point	Boiling Temperature at Distillation Point,°C					
	Diesel		Methanol		Meth.-Cat.	
	Cold	Hot	Cold	Hot	Cold	Hot
IBP	269	292	312	285	285	310
10% point	381	384	389	392	381	387
20% point	414	414	415	415	410	415
30% point	440	436	440	435	436	439
40% point	469	460	471	456	467	469
50% point	502	485	514	482	506	512
60% point	555	519	589	518	558	571
70% point	---	580	---	588	---	---
80% point	---	---	---	---	---	---
90% point	---	---	---	---	---	---
EP	---	---	---	---	---	---
Recovery, % @ 606°C	64	72	61	72	65	63

c. Fractionation by Relative Polarity

The composition of the soluble organic fraction of the total particulate is complex, and its separation into individual compounds is very difficult. Fractionation of the SOF by high performance liquid chormatography (HPLC) separates the soluble portion into a series of fractions of increasing molecular polarity. Figures 21 through 27 show the HPLC chromatographic outputs for direct comparison of the relative concentration of increasingly polar compounds from cold and hot transient operation of the diesel engine and the dual-fuel engine.

Each figure contains three traces, one representing the solvent composition, a second representing the ultraviolet detector response, and the other representing the fluorescence detector response. Initially, the solvent is composed of 95 percent hexane and 5 percent methylene chloride, a relatively non-polar mixture. This solvent mixture is used from the start of the chromatogram to 17 minutes into the elution period. During this period, non-polar compounds elute. BaP elutes at eight minutes into the run. Many non-polar PNA compounds also elute during this period, and give ultraviolet and fluorescence responses. After 17 minutes, the polarity of the solvent is increased at a rate of 5 percent methylene chloride per minute. During this transition period of solvent polarity, more polar compounds are eluted, giving fluorsecence and ultraviolet spectra. At the end of this transition period (36 minutes into the run), the solvent is 100 percent methylene chloride and 9-fluorenone elutes. With 100 percent methylene chloride, even more polar compounds elute. Acridine elutes during this polar period (at about 70 minutes).

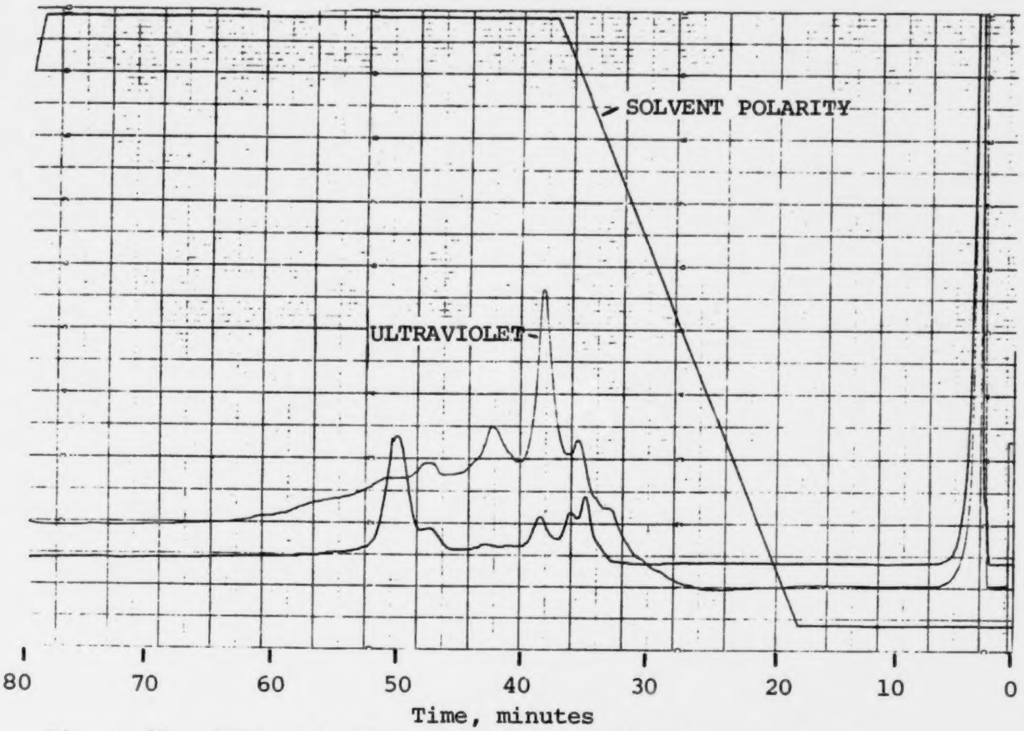

Figure 21. HPLC response to cold-start diesel transient SOF

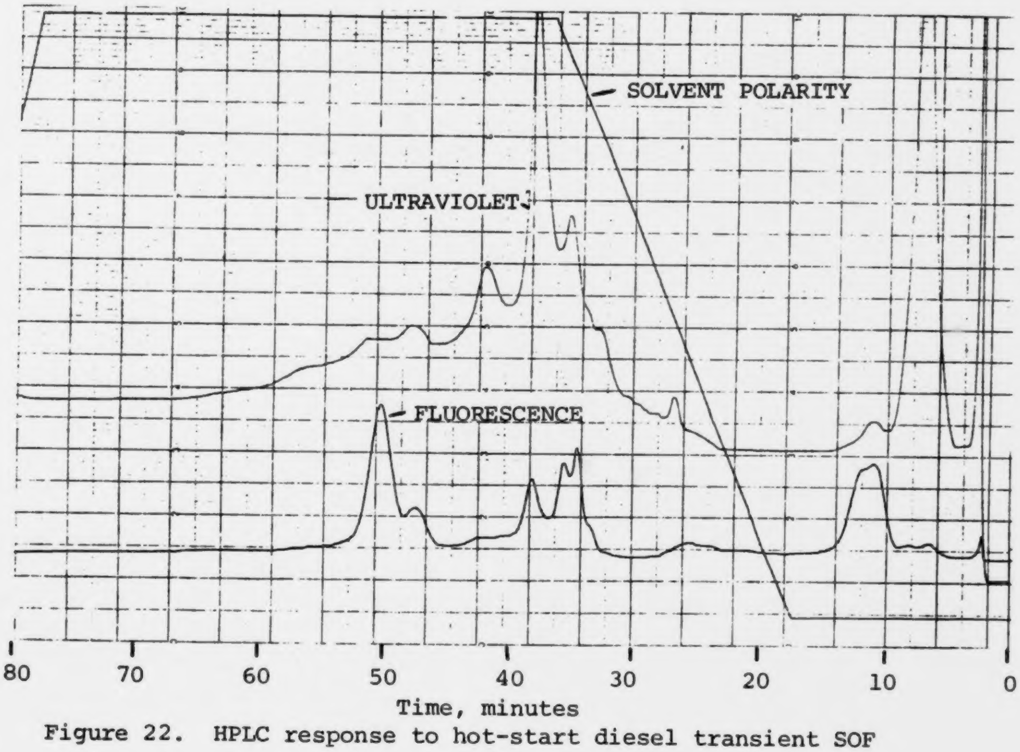

Figure 22. HPLC response to hot-start diesel transient SOF

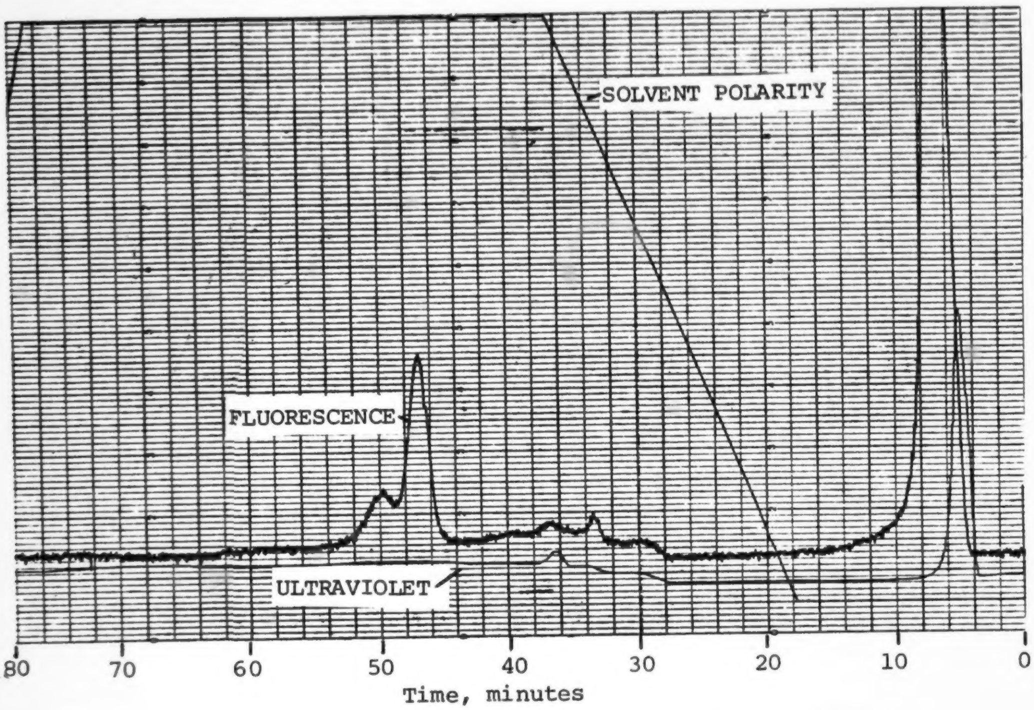

Figure 23. HPLC response to cold-start methanol transient SOF

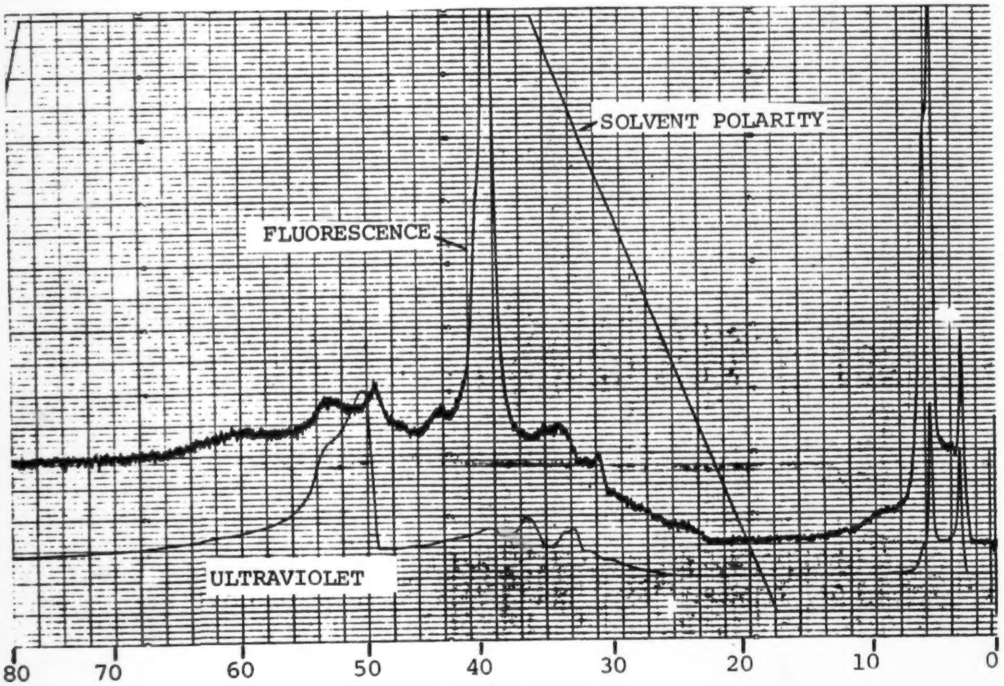

Figure 24. HPLC response to hot-start methanol transient SOF

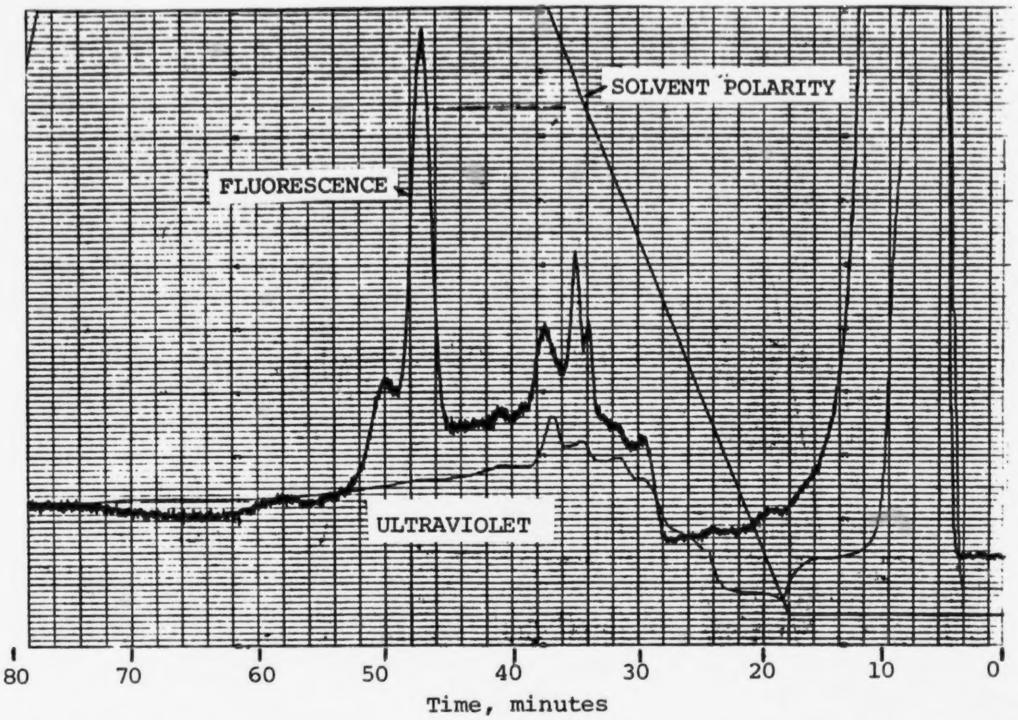

Figure 25. HPLC response to cold-start methanol-catalyst transient SOF

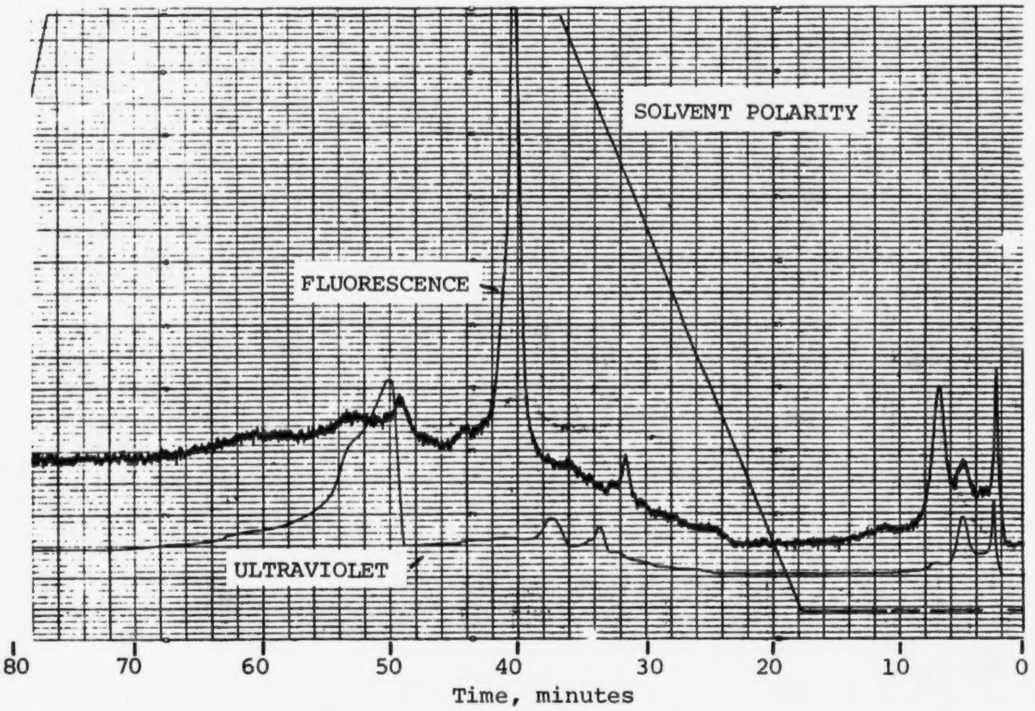

Figure 26. HPLC response to hot-start methanol-catalyst transient SOF

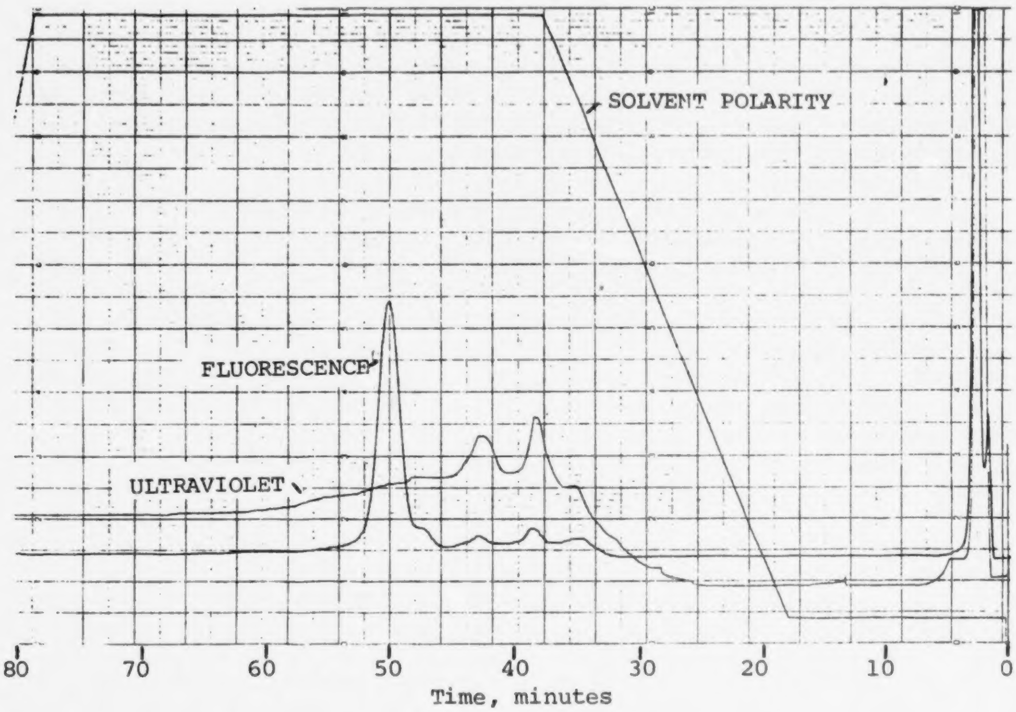

Figure 27. HPLC response to hot-start ethanol-catalyst transient SOF

Figures 21 and 22 show the chormatograms from the HPLC fractionation of the SOF from the cold-start and hot-start transient tests of the diesel configuration. Fluorescence from the cold-start indicated non-polar PNA compounds (such as BaP) with only slight response at the end of the transition region and some response at 50 minutes, near the end of the polar compound region. Ultraviolet response seemed relatively high at the end of the transition region. Fluorescence from the hot-start indicated few non-polar compounds, but did show a peak near the end of the non-polar region. Generally, fluorescence from the transition region was minimal, with some response near the beginning and end of the polar solvent region. For some reason, the ultraviolet response was very high, particularly in the region where BaP elutes and at the beginning of the polar region.

HPLC chromatograms for the cold- and hot-start transient tests of the methanol configuration are given in Figures 23 and 24, respectively. Fluorescence from the cold-start with methanol was relatively strong in the non-polar PNA region of the chormatogram. No fluorescence was noted in the transition region, but there were definite peaks around 47 and 50 minutes of the polar region. Ultraviolet response was minimal for the cold-start with methanol. Fluorescence from the hot-start with methanol showed some presence of BaP-type compounds, but not to the extent noted from the cold-start. Similar to the cold-start, there was no response in the transitional region for the hot-start methanol sample. Also, there was a relatively strong fluorescence peak around 40 minutes, about the beginning of the polar region, and an absence of the compounds which had been seen around 50 minutes. A significant ultraviolet response was noted at 50 minutes.

Results from cold- and hot-start transient tests of the methanol-catalyst configuration are shown in Figures 25 and 26. The fluorescence responses from the cold-start sample were extremely large in the non-polar region. Several compounds were also noted at the end of the transition region. As with the cold-start methanol, there was a definite fluorescence peak around 47 and 50 minutes, but it was significantly larger when the catalyst was used. The ultraviolet response was fairly significant in the non-polar region as well as near the end of the transition region. As may have been expected with a hot-start catalyst sample, fluorescence in the non-polar region was significantly reduced from that of the cold-start with catalyst. It is interesting that the catalyst seemed to have no effect in reducing the fluorescence peak noted around 40 minutes or the ultraviolet peak around 50 minutes noted for the hot-start methanol configuration. In fact, the traces from the hot-start methanol and the hot-start methanol-catalyst configuration are almost identical beyond the non-polar region.

A sample from the hot-start ethanol-catalyst configuration was submitted for HPLC fractionation and is shown in Figure 27. The fluorescence emissions were noted early in the non-polar region and in the polar region at about 50 minutes. The ultraviolet response was minimal except for the near transition-polar region, where it was significant.

The hot-start results are weighted more heavily than cold in the composite calculations, so they are considered very important in total population exposure. The hot-start sample from the methanol configuration had more fluorescence response in the early polar region and less response in the non-polar region than the hot-start sample from the diesel configuration. The catalyst appeared to have little effect on the hot-start methanol fluorescence response, although the catalyst significantly affected the cold-start results. The response from the ethanol-catalyst hot-start sample was very different from the methanol-catalyst hot-start, in that the ethanol-catalyst sample had strong fluorescence peaks around 3 minutes and 50 minutes, and had a relatively high ultraviolet peak around 40 minutes.

d. Benzo(a)pyrene

Benzo(a)pyrene (BaP) is often an indicator of PNA content in the soluble organic fraction. BaP content was determined for transient composite SOF from diesel, methanol, ethanol, methanol-catalyst, and ethanol-catalyst test configurations. In addition, BaP content was determined for 7-mode composite SOF from diesel, methanol, methanol-catalyst, and ethanol+water test configurations. Transient composite SOF was made up of the organic extract from one cold-start, plus six hot-start total particulate samples collected on 20x20 inch filters. The 7-mode composite SOF was made up by combining portions of individual modal extracts into one common sample on the basis of modal emission rate of total particulate, the modal weighting factor, and the modal percentage of extractables.

The BaP results from both the transient composite and the 7-mode composite from the various test configurations are given in Table 52. The brake specific BaP was also computed for comparison purposes, and takes into account the BaP concentration, SOF rate and the work produced. In all cases, the BaP was lower for the 7-mode composite than for the transient composite from a given configuration.

TABLE 52. SUMMARY OF TRANSIENT COMPOSITE AND 7-MODE COMPOSITE BENZO(A)PYRENE EMISSIONS FROM THE VOLVO TEST ENGINES

Test Configuration	Cycle Composite	Benzo(a)pyrene Emissions		
		μg BaP/mg SOF	μg BaP/kW-hr	μg BaP/kg fuel
Diesel	Transient	0.0168	3.7	13.
	7-Mode	0.0032	0.64	2.4
Methanol	Transient	0.0061	1.7	3.2
	7-Mode	0.0043	0.86	1.8
Methanol -Catalyst	Transient	0.0055	0.33	0.60
	7-Mode	0.0011	0.08	0.17
Ethanol	Transient	0.0017	0.32	0.74
	7-Mode	---		
Ethanol -Catalyst	Transient	0.0921	3.7	8.3
	7-Mode	---		
Ethanol +Water	Transient	---		
	7-Mode	0.0064	1.2	2.4

Generally, unburned fuel-like matter is emitted during light load operation where the diesel combustion mixture is very lean. Levels of BaP from transient operation in the methanol, methanol-catalyst and ethanol+water configuration were all very similar and lower than for the diesel configuration. The 7-mode composite BaP level from the diesel and methanol configurations were somewhat similar. The catalyst was effective in reducing the 7-mode composite BaP level from the methanol configuration, but had little effect on the transient composite BaP level. In contrast, when ethanol was used, the catalyst significantly increased the transient composite BaP level. The reason for such an increase is puzzling, but may be due to the relative amount of oxygen introduced into the combustion chamber as fuel.

e. Ames Response

The Ames test, as employed in this program, refers to a bacterial mutagenesis plate assay with Salmonella typhimurium according to the method of Ames.(13) This bioassay determines the ability of chemical compounds or mixtures to cause mutation of DNA in the bacteria, positive results occurring when histidine-dependent strains of bacteria revert (or are mutated) genetically to forms which can synthesize histidine on their own. Samples of the soluble organic fraction representing transient composites and 7-mode composites, were submitted for bioassay over five tester strains, TA1535, TA1537, TA1538, TA98 and TA100.

All five strains are histidine-dependent cells by virtue of mutations within the histidine functional genetic unit. When these histidine-dependent cells are grown on minimal medium agar plates containing a limited amount of histidine, only those cells that revert to histidine independence are able to form colonies. The trace amount of histidine allows all the bacteria plated to undergo a few divisions, which is essential for mutagenesis to occur. It is these histidine-independent revertants which are scored as colonies against a slight background growth consisting of histidine-requiring cells that have depleted the histidine present within the minimal medium.

In addition to mutations in the histidine functional genetic unit, all the tester strains have a defective lipopolysaccharide coat which allows large molecules to permeate the bacterial wall, thus increasing bacterial sensitivity to mutagenic aromatic compounds. Furthermore, a U.V. mutation decreases bacterial sensitivity to additional mutagenic agents. TA1535 and its plasmid-containing counterpart, TA100, detect base pair substitutions, while TA1537 (and TA1538 with its plasmid-containing counterpart, TA98) respond to frameshift mutagens. The plasmids present in TA98 and TA100 are believed to cause an increase in error-prone DNA repair which leads to many more mutations. Thus, the five tester strains in tandem provide a very sensitive method for the detection of potential mutagenic environmental samples.

Samples of the organic soluble fraction from transient composites and 7-mode composites of the various engine configurations were submitted for bioassay over the five tester strains, with and without metabolic activation. The extractables were tested in two separate groups. The first group consisted of transient composite SOF samples from methanol, methanol-catalyst, ethanol, and ethanol-catalyst configurations. The second group consisted of transient composite samples from methanol and diesel configuration along with 7-mode composite samples from the diesel, methanol, methanol-catalyst and the ethanol+water configurations. Results from these tests are given in Table 53. In addition, the second group also contained samples from seven individual steady-state modes from the diesel, methanol and methanol-catalyst configurations. These individual modal SOF samples were tested using only the TA98 tester strain, with and without metabolic activation. Results from these individual modal tests are given in Table 54.

Results given in both Tables 53 and 54 include the slope of dose response, which represents the statistically determined slope of the function representing revertants per plate versus micrograms SOF dosage. This result is termed "specific activity," and is an indication of the level of mutagenic potential of the extract. In Table 53, results are also given in terms of brake specific response, which represents the specific activity multiplied by the SOF brake specific emission rate. The units for the brake specific response are then

$$\frac{\text{revertants/plate}}{\text{kW-hr}}$$

The "revertants per plate" per "kW-hr" is useful for comparison purposes, but has no practical meaning. Samples from the first group were tested twice over a period of one and one-half months. The specific activities from these replicate tests are given in Table 53 under the headings, "Test 1" and "Test 2." The average of these specific activities was used in conjunction with the brake specific emission of SOF to calculate the brake specific response.

Within the first group, there was good repeatability between the two tests from both the methanol and the ethanol configurations, but not when the catalyst was used. The ethanol configuration had twice the specific activity of the methanol configuration. The specific activities of both the methanol and ethanol configurations were substantially higher when the catalyst was used. Since the catalyst reduced the SOF emission, the brake specific response from the methanol-catalyst configuration was almost the same as from the methanol configuration. The specific activity of the ethanol-catalyst configuration increased greatly, so that the brake specific response was generally greater than from the ethanol configuration, even though the SOF emission was substantially reduced by the catalyst.

TABLE 53. SUMMARY OF AMES RESPONSE TO TRANSIENT COMPOSITE AND MODAL COMPOSITE SOF FROM THE VOLVO TEST ENGINES[a]

Engine Test Configuration	Total Part. Rate g/kW-hr	Soluble Organic Fract. g/kW-hr	Metab. Activ. Status	Strain TA98			Strain TA100			Strain TA1535			Strain TA1537			Strain TA1538		
				Specific Activity[b]		Brake Specific Response[c]	Specific Activity[b]		Brake Specific Response[c]	Specific Activity[b]		Brake Specific Response[c]	Specific Activity[b]		Brake Specific Response[c]	Specific Activity[b]		Brake Specific Response[c]
				Test 1	Test 2		Test 1	Test 2		Test 1	Test 2		Test 1	Test 2		Test 1	Test 2	
Methanol Trans.[1]	0.39	0.29	No	1.5	2.3	0.55	3.2	5.1	1.20	0.0	0.0	0.0	0.3	0.4	0.10	1.1	0.8	0.28
			Yes	3.4	2.8	0.90	2.7	2.9	0.81	0.2	0.1	0.04	0.7	0.6	0.19	3.4	3.8	1.04
Meth-Cat. Trans.[1]	0.33	0.05	No	21.8	17.2	0.98	9.3	24.4	0.84	0.0	0.2	0.01	19.2	10.9	0.75	35.1	12.5	1.19
			Yes	14.1	19.6	0.84	8.3	40.1	1.21	0.4	2.1	0.06	3.0	16.3	0.48	6.5	22.8	0.73
Ethanol Trans.[1]	0.35	0.19	No	4.3	3.8	0.77	9.8	11.8	2.05	0.0	0.1	0.01	1.1	1.0	0.20	2.3	3.8	0.58
			Yes	6.8	7.0	1.31	7.8	6.9	1.40	0.2	0.4	0.06	3.0	1.2	0.40	5.4	6.0	1.08
Eth.-Cat. Trans.[1]	0.38	0.04	No	37.5	42.8	1.61	4.0	57.7	1.23	0.0	1.1	0.02	87.4	74.7	3.24	5.8	51.8	1.15
			Yes	21.8	66.3	1.76	18.2	141	3.18	0.2	0.6	0.02	33.2	438	9.42	37.	308	6.90
Repeat Methanol Trans.[2]	0.39	0.29	No	0.4	--	0.12	1.7	--	0.49	0.0	--	0.0	0.1	--	0.03	0.2	--	0.06
			Yes	0.6	--	0.17	2.2	--	0.64	0.5	--	0.15	0.1	--	0.03	0.4	--	0.12
Diesel Trans.[2]	0.70	0.22	No	2.1	--	0.46	8.8	--	1.94	0.0	--	0.0	1.6	--	0.35	1.8	--	0.40
			Yes	2.5	--	0.55	6.2	--	1.36	0.2	--	0.04	1.0	--	0.22	2.4	--	0.53
Diesel 7-Mode[2]	0.69	0.20	No	0.9	--	0.18	16.3	--	3.26	0.0	--	0.0	0.2	--	0.04	1.2	--	0.24
			Yes	0.6	--	0.12	3.5	--	0.70	0.3	--	0.06	0.6	--	0.12	0.8	--	0.16
Methanol 7-Mode[2]	0.30	0.20	No	2.3	--	0.46	3.9	--	0.78	0.0	--	0.0	0.3	--	0.06	1.2	--	0.24
			Yes	2.8	--	0.56	3.6	--	0.72	0.1	--	0.02	0.5	--	0.10	0.8	--	0.16
Meth.-Cat. 7-Mode[2]	0.51	0.07	No	1.3	--	0.09	4.4	--	0.31	0.0	--	0.0	0.5	--	0.04	0.8	--	0.06
			Yes	2.2	--	0.15	5.2	--	0.36	0.1	--	0.01	0.5	--	0.04	2.3	--	0.16
Eth.+Water 7-Mode[2]	0.33	0.19	No	0.04	--	0.08	1.6	--	0.30	0.0	--	0.0	0.0	--	0.0	0.2	--	0.04
			Yes	0.06	--	0.11	1.4	--	0.27	0.1	--	0.02	0.1	--	0.02	0.5	--	0.10

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[a] SOF was submitted and tested in two separate groups. The first group is designated by a "1" and the second group is designated by a "2" in the "Engine Test Configuration" column. In the first group, duplicate tests were conducted in order to establish test to test repeatability.

[b] Specific activity results from statistical analysis of revertants of bacteria culture per microgram of SOF dose

[c] Brake specific response has units of: millions of revertants/plate per kilowatt hour

TABLE 54. SUMMARY OF AMES RESPONSE TO INDIVIDUAL MODAL SAMPLES OF SOF FROM THE VOLVO TEST ENGINES

Sample Test Condition rpm/%load	TA98 Metabolic Activation Status	Diesel Configuration			Methanol Configuration			Meth.-Cat. Configuration		
		Soluble Fraction g SOF/hr	Specific Activity^{a} 10^{6}rev./μg SOF	Specific Rate^{b} 10^{6}rev./hr	Soluble Fraction g SOF/hr	Specific Activity^{a} 10^{6}rev/μg SOF	Specific Rate^{b} 10^{6}rev./hr	Soluble Organ.Frac. g SOF/hr	Specific Activity^{a} 10^{6}rev./μg SOF	Specific Rate^{b} 10^{6}rev./hr
1400/2	No	17.0	0.6	10.2	37.	0.5	18.5	15.	2.7	40.5
	Yes		0.6	10.2		0.5	18.5		2.8	42.0
1400/50	No	9.9	1.7	16.8	3.2	9.9	31.7	1.2	6.8	8.2
	Yes		2.2	21.8		9.9	31.7		15.7	18.8
1400/100	No	4.8	2.6	12.5	0.6	11.0	6.6	0.6	1.2	0.7
	Yes		1.2	5.8		2.6	1.6		0.9	0.5
Idle	No	6.4	0.9	5.8	4.6	0.6	2.8	1.2	5.9	7.1
	Yes		2.3	14.7		0.6	2.8		6.2	7.4
2200/100	No	7.3	10.6	77.4	1.4	12.8	17.9	2.3	7.9	18.2
	Yes		4.7	34.3		12.3	17.2		17.3	39.8
2200/50	No	7.6	2.8	21.3	4.4	6.9	30.4	1.8	6.1	11.0
	Yes		1.6	12.2		6.7	29.5		16.5	29.7
2200/2	No	43.	0.8	34.4	52.	0.5	26.0	15.	2.3	34.5
	Yes		0.7	30.1		0.7	36.4		4.5	67.5
7-Mode Composite	No	12.2^{d}	0.9^{d}	11.0^{c}	12.5^{d}	2.3^{d}	28.8^{c}	4.5^{d}	1.3^{d}	5.8^{c}
	Yes		0.6^{d}	7.3^{c}		2.8^{d}	35.0^{c}		2.2^{d}	9.9^{c}
7-Mode Brake Spec.	No	--	--	0.18^{d}	--	--	0.46^{d}	--	--	0.09^{d}
	Yes	--	--	0.12	--	--	0.56^{d}	--	--	0.16^{d}

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[a] Specific activity has units of: millions revertants/plate per microgram of SOF dose

[b] Specific rate has units of : millions revertants/plate per hour

[c] Computed on the basis of 7-mode brake specific response from composite sample and a 7-mode composite power output of 62.2kW

[d] Data transferred from Table 53.

Note: A blank filter was processed, specific activity of TA98 with metabolic activation was 0.2, without metabolic activation was 0.4 10^{6} revertants/plate per microgram dose

The second group of SOF samples contained another sample from the methanol configuration in order to tie the two test groups together for comparison purposes. Unfortunately, the Ames test response from the repeat methanol sample did not resemble the results from the first group. The poor "repeatability" could have been due to a change in the bacteria strains which may have occurred during the four-month time period between the testing of the two groups. Within the second group, the diesel transient SOF sample had higher specific activities and brake specific responses than the methanol transient SOF sample. If it could be assumed that the results from both test groups (for the methanol configuration) were equivalent, it would imply that the Ames response to the transient diesel samples would approach the magnitude of the response to the transient samples from the dual-fuel configurations with catalyst.

The 7-mode composite SOF samples were tested for Ames response as part of the second group. The modal composite diesel generally had greater specific activity than the modal composite methanol, although this trend varied with tester strain. Strain TA98 indicated that modal composite methanol activity was higher than modal composite diesel activity, whereas strain TA100 indicated an opposite trend and the other strains showed no real difference between the two. Comparisons between specific activities of the modal composites from the methanol and the methanol-catalyst configurations showed minimal differences, but the brake specific response was lower with the catalyst due to the significant reductions in brake specific SOF emission. Generally, the specific activity from the modal composite of the ethanol+water configuration was lower than from the methanol configuration, at least for strains TA98 and TA100.

The individual modal responses using TA98 are given in Table 54 and indicate that the specific activity from idle and the "two percent load" conditions were about the same for both the diesel and the methanol configurations. Above these light-load conditions, the specific activity from the methanol configuration was significantly higher than that of the diesel configuration. These trends in steady-state responses may explain the different trends noted for transient composite and steady-state modal composite samples. Modal composite results, using TA98, indicated greater specific activity for the methanol configuration than for the diesel configuration. Trends from the transient test were just the opposite. Considering the individual modal data, the 7-mode composite results from the methanol configuration would be expected to yield higher activities because the 7-mode composite included more heavily loaded operation than the transient test. The sepcific activity of the transient composite sample from the methanol-catalyst configuration was higher than for the modal composite sample. Individual modal data indicated that the specific activity, with the catalyst, increased during the light loads and decreased during the maximum torque mode, with little or no change during the maximum power mode. Once again, considering the modal data, the more lightly-loaded transient test results would be expected to have a higher specific activity than the more heavily loaded 7-mode composite.

Overall, Ames response to transient composite SOF samples indicated that methanol and ethanol configurations had less potential for bioactivity than the diesel configuration, but that the addition of the catalyst may have substantially increased the level of bioactivity above that of the diesel configuration. Seven-mode composite results indicated that the methanol had a higher potential for bioactivity than the diesel, considering only strain TA98, and that the catalyst actually reduced this potential. Individual modal data indicated that the methanol configuration had about the same potential for biological activity as the diesel configuration, at the light load conditions, where only diesel fuel was comsumed. This potential appears to have increased as more methanol was substituted for diesel fuel; yet as more methanol was substituted, the quantity of SOF decreased substantially. Individual modal data indicated that the catalyst significantly increased the potential for bioactivity during the light loads.

In addition to testing various soluble organic fractions extracted from particulate samples collected on Pallflex filter media, a blank filter was also extracted using the same procedure. The resulting extract (3.1 mg) was processed for Ames response using strain TA98. The results indicated that some activity was apparent. This response, although notable for a blank, may be the result of background activity scaled up by the use of a small sample.

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APPENDIX A

THIRTEEN MODE FTP TEST RESULTS - ALL CONFIGURATIONS

TABLE A-1. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 C DIESEL
TEST:06-01 FUEL: EM-465-F PROJECT:11-5830-006
BAROMETER 29.15
DATE: 03/20/81

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 500.	0.	.0	.020	2.45	3.9	.889	480.	452.	1.68	330.	32.	61.	64.	1
2	2	INTER / 1400.	14.	2.0	.065	7.15	3.9	.890	488.	239.	1.83	195.	102.	99.	117.	2
3	25	INTER / 1400.	217.	31.8	.145	7.31	3.9	.899	312.	439.	4.26	615.	65.	178.	366.	3
4	50	INTER / 1400.	439.	64.4	.250	7.86	3.9	.910	288.	191.	6.89	1200.	66.	83.	778.	4
5	75	INTER / 1400.	665.	97.4	.360	9.01	3.9	.917	188.	111.	8.79	1650.	50.	55.	1219.	5
6	100	INTER / 1400.	879.	128.9	.484	9.99	3.9	.924	112.	332.	10.61	1755.	34.	183.	1455.	6
7		IDLE / 500.	0.	.0	.020	2.29	4.5	.901	488.	319.	1.59	360.	35.	45.	75.	7
8	100	RATED / 2200.	778.	179.4	.731	18.51	4.5	.423	100.	319.	8.88	1200.	53.	316.	1794.	8
9	75	RATED / 2200.	586.	135.0	.566	16.55	4.5	.919	120.	506.	7.52	900.	58.	457.	1221.	9
10	50	RATED / 2200.	388.	89.4	.420	14.80	4.5	.915	136.	412.	6.21	590.	58.	334.	714.	10
11	25	RATED / 2200.	198.	45.6	.270	12.96	4.5	.910	200.	319.	4.60	385.	73.	224.	401.	11
12	2	RATED / 2000.	16.	3.4	.153	11.56	4.5	.904	496.	506.	2.71	185.	166.	333.	180.	12
13		IDLE / 500.	0.	.0	.020	2.34	4.5	.901	496.	412.	1.68	340.	34.	55.	67.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	27.52	51.42	54.49	******	******	*****	.0080	.0687	.117	.983	.0084	5.0	.987	*****	.067	1
2	26.10	25.34	30.04	51.19	49.70	58.91	.0091	.0687	.133	.982	.0090	-.9	.997	1.967	.080	2
3	7.49	20.43	42.01	2.05	5.59	11.50	.0199	.0687	.290	.961	.0204	2.3	.998	.274	.080	3
4	4.42	5.55	51.80	1.03	1.29	12.07	.0319	.0687	.465	.939	.0322	.9	.998	.233	.080	4
5	2.31	2.54	56.47	.51	.56	12.51	.0401	.0687	.584	.924	.0406	1.3	1.003	.221	.080	5
6	1.16	6.29	50.14	.26	1.42	11.29	.0486	.0687	.708	.910	.0487	.1	1.010	.223	.080	6
7	29.67	38.52	63.91	******	******	*****	.0086	.0687	.126	.984	.0080	-7.8	.994	*****	.067	7
8	1.21	7.22	40.90	.30	1.76	10.00	.0397	.0687	.578	.923	.0411	3.5	1.055	.232	.080	8
9	1.70	13.47	35.94	.43	3.39	9.04	.0344	.0687	.501	.934	.0351	2.2	1.042	.241	.080	9
10	2.30	13.27	28.38	.65	3.74	7.99	.0285	.0687	.415	.944	.0292	2.5	1.032	.273	.080	10
11	4.49	13.84	24.79	1.59	4.91	8.80	.0209	.0687	.305	.958	.0218	4.4	1.022	.347	.080	11
12	18.11	36.32	19.60	48.67	97.61	52.66	.0133	.0687	.193	.974	.0133	.3	1.015	2.649	.080	12
13	28.47	46.93	56.94	******	******	*****	.0084	.0687	.123	.983	.0084	.1	.992	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- =	1.040	GRAM/KW-HR	(.776	GRAM/BHP-HR)
BSCO ------- =	3.084	GRAM/KW-HR	(2.301	GRAM/BHP-HR)
BSNOX ------ =	10.829	GRAM/KW-HR	(8.078	GRAM/BHP-HR)
BSHC + BSNOX =	11.869	GRAM/KW-HR	(8.855	GRAM/BHP-HR)
CORR. BSFC - =	.263	KG/KW-HR	(.432	LBS/BHP-HR)

NO_x CORRECTION APPLIED

TABLE A-2. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 C DIESEL
TEST: 06-02 FUEL: EM-465-F PROJECT:11-5830-006
BAROMETER 29.04
DATE: 03/20/81

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 500.	0.	.0	.021	2.37	4.5	.902	488.	372.	1.63	340.	37.	56.	75.	1
2	2	INTER / 1400.	18.	2.6	.072	7.13	4.5	.903	448.	399.	2.02	240.	94.	165.	146.	2
3	25	INTER / 1400.	221.	32.4	.150	7.30	4.5	.910	316.	425.	4.40	645.	66.	173.	390.	3
4	50	INTER / 1400.	441.	64.6	.250	7.72	4.5	.919	280.	159.	7.07	1245.	63.	68.	795.	4
5	75	INTER / 1400.	662.	97.0	.357	8.85	4.5	.924	204.	159.	9.09	1710.	52.	75.	1221.	5
6	100	INTER / 1400.	882.	129.3	.488	9.97	4.5	.931	128.	425.	10.96	1785.	38.	228.	1455.	6
7		IDLE / 500.	0.	.0	.018	2.26	4.1	.885	480.	412.	1.59	340.	32.	54.	64.	7
8	100	RATED / 2200.	773.	178.1	.734	18.41	4.1	.917	112.	359.	8.88	1215.	60.	357.	1810.	8
9	75	RATED / 2200.	579.	133.4	.567	16.42	4.1	.912	124.	532.	7.52	900.	60.	481.	1212.	9
10	50	RATED / 2200.	387.	89.1	.418	14.62	4.1	.906	128.	439.	6.21	595.	54.	355.	710.	10
11	25	RATED / 2200.	193.	44.4	.262	12.70	4.1	.898	236.	306.	4.46	380.	86.	215.	392.	11
12	2	RATED / 2200.	15.	3.4	.146	11.49	4.1	.890	472.	425.	2.60	180.	157.	279.	172.	12
13		IDLE / 500.	0.	.0	.021	2.30	4.9	.906	480.	385.	1.59	330.	37.	59.	75.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	GRAMS/KW-HR HC	GRAMS/KW-HR CO	GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR/ FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	28.89	43.73	58.82	******	******	*****	.0090	.0687	.130	.984	.0082	-8.9	.996	*****	.067	1
2	21.71	38.24	33.88	36.18	63.74	56.47	.0101	.0687	.147	.980	.0100	-1.1	1.004	1.661	.080	2
3	7.36	19.17	43.19	2.05	5.34	12.03	.0207	.0687	.301	.960	.0210	1.6	1.004	.277	.080	3
4	4.20	4.51	52.93	.98	1.05	12.29	.0326	.0687	.474	.937	.0330	1.4	1.006	.231	.080	4
5	2.43	3.52	57.03	.54	.78	12.58	.0405	.0687	.590	.921	.0420	3.7	1.010	.218	.080	5
6	1.28	7.79	49.67	.29	1.76	11.26	.0492	.0687	.716	.907	.0502	2.2	1.016	.223	.080	6
7	29.03	49.50	59.01	******	******	*****	.0080	.0687	.117	.984	.0080	-.6	1.001	*****	.067	7
8	1.36	8.12	41.11	.34	2.01	10.16	.0400	.0687	.583	.923	.0411	2.7	1.063	.233	.080	8
9	1.75	14.15	35.62	.45	3.61	9.08	.0347	.0687	.505	.934	.0351	1.4	1.053	.242	.080	9
10	2.16	14.14	28.32	.61	3.98	7.97	.0287	.0687	.418	.944	.0292	1.7	1.043	.270	.080	10
11	5.45	13.68	24.88	1.93	4.85	8.82	.0207	.0687	.302	.959	.0212	2.2	1.033	.343	.080	11
12	17.99	31.88	19.60	45.80	81.17	49.92	.0127	.0687	.186	.975	.0127	-.0	1.027	2.480	.080	12
13	29.08	46.33	58.67	******	******	*****	.0092	.0687	.134	.984	.0080	-13.5	1.001	*****	.067	13

CYCLE COMPOSITF USING 13-MODE WEIGHT FACTORS

BSHC ------- = 1.056 GRAM/KW-HR (.788 GRAM/BHP-HR)
BSCO ------- = 3.277 GRAM/KW-HR (2.444 GRAM/BHP-HR)
BSNOX ------ = 10.952 GRAM/KW-HR (8.170 GRAM/BHP-HR) NO$_x$ CORRECTION APPLIED
BSHC + BSNOX = 12.007 GRAM/KW-HR (8.957 GRAM/BHP-HR)
CORR. BSFC - = .262 KG/KW-HR (.430 LBS/BHP-HR)

TABLE A-3. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 C DIESEL
TEST:06-01 FUEL: EM-465-F PROJECT:11-5830-006
BAROMETER 29.15
DATE: 03/20/81

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 500.	0.	.0	.020	2.45	3.9	.889	480.	452.	1.68	330.	32.	61.	72.	1
2	2	INTER / 1400.	14.	2.0	.065	7.15	3.9	.890	488.	239.	1.83	195.	102.	99.	132.	2
3	25	INTER / 1400.	217.	31.8	.145	7.31	3.9	.899	312.	439.	4.26	615.	65.	178.	407.	3
4	50	INTER / 1400.	439.	64.4	.250	7.86	3.9	.910	288.	191.	6.89	1200.	66.	83.	855.	4
5	75	INTER / 1400.	665.	97.4	.360	9.01	3.9	.917	188.	111.	8.79	1650.	50.	55.	1330.	5
6	100	INTER / 1400.	879.	128.9	.484	9.99	3.9	.924	112.	332.	10.61	1755.	34.	183.	1575.	6
7		IDLE / 500.	0.	.0	.020	2.29	4.5	.901	488.	319.	1.59	360.	35.	45.	84.	7
8	100	RATED / 2200.	778.	179.4	.731	18.51	4.5	.923	100.	319.	8.88	1200.	53.	317.	1943.	8
9	75	RATED / 2200.	586.	135.0	.566	16.55	4.5	.919	120.	506.	7.52	900.	58.	458.	1328.	9
10	50	RATED / 2200.	388.	89.4	.420	14.80	4.5	.915	136.	412.	6.21	590.	58.	334.	781.	10
11	25	RATED / 2200.	198.	45.6	.270	12.96	4.5	.910	200.	319.	4.60	385.	73.	224.	441.	11
12	2	RATED / 2000.	16.	3.4	.153	11.56	4.5	.904	496.	506.	2.71	185.	166.	333.	199.	12
13		IDLE / 500.	0.	.0	.020	2.34	4.5	.901	496.	412.	1.68	340.	34.	55.	75.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	27.52	51.44	61.27	******	******	*****	.0080	.0687	.117	.983	.0084	5.0	.987	*****	.067	1
2	26.10	25.35	33.74	51.19	49.71	66.17	.0091	.0687	.133	.982	.0090	-.9	.997	1.967	.080	2
3	7.49	20.44	46.72	2.05	5.59	12.78	.0199	.0687	.290	.961	.0204	2.3	.998	.274	.080	3
4	4.42	5.56	56.96	1.03	1.29	13.27	.0319	.0687	.465	.939	.0322	.9	.998	.233	.080	4
5	2.31	2.54	61.61	.51	.56	13.65	.0401	.0687	.584	.924	.0406	1.3	1.003	.221	.080	5
6	1.16	6.29	54.25	.26	1.42	12.22	.0486	.0687	.708	.910	.0487	.1	1.010	.223	.080	6
7	29.66	38.53	70.94	******	******	*****	.0086	.0687	.126	.984	.0080	-7.8	.994	*****	.067	7
8	1.21	7.22	44.30	.30	1.76	10.83	.0397	.0687	.578	.923	.0411	3.5	1.055	.232	.080	8
9	1.70	13.47	39.09	.43	3.39	9.84	.0344	.0687	.501	.934	.0351	2.2	1.042	.241	.080	9
10	2.30	13.28	31.02	.65	3.74	8.74	.0285	.0687	.415	.944	.0292	2.5	1.032	.273	.080	10
11	4.49	13.84	27.26	1.59	4.91	9.67	.0209	.0687	.305	.958	.0218	4.4	1.022	.347	.080	11
12	18.11	36.33	21.67	48.67	97.65	58.25	.0133	.0687	.193	.974	.0133	.3	1.015	2.649	.080	12
13	28.47	46.95	63.21	******	******	*****	.0084	.0687	.123	.983	.0084	-.2	.992	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC -------- = 1.040 GRAM/KW-HR (.776 GRAM/BHP-HR)
BSCO -------- = 3.085 GRAM/KW-HR (2.302 GRAM/BHP-HR)
BSNOX ------- = 11.813 GRAM/KW-HR (8.813 GRAM/BHP-HR)
BSHC + BSNOX = 12.853 GRAM/KW-HR (9.589 GRAM/BHP-HR)
CORR. BSFC - = .263 KG/KW-HR (.432 LBS/BHP-HR)

TABLE A-3 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 C DIESEL
TEST: 06-01 FUEL: EM-465-F PROJECT: 11-5830-006
BAROMETER 29.15
DATE: 03/20/81

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	F/A RATIO FUEL CARBON	F/A RATIO EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0196	.0196	.0000	.0000	.0196	13.8764	.9835	.0063	.0080	.0080	.0080	0.0000
2	.0650	.0650	.0000	.0000	.0650	13.8764	.9823	.0063	.0091	.0091	.0091	0.0000
3	.1451	.1451	.0000	.0000	.1451	13.8764	.9609	.0063	.0199	.0199	.0199	0.0000
4	.2502	.2502	.0000	.0000	.2502	13.8764	.9390	.0063	.0319	.0319	.0319	0.0000
5	.3598	.3598	.0000	.0000	.3598	13.8764	.9238	.0063	.0401	.0401	.0401	0.0000
6	.4838	.4838	.0000	.0000	.4838	13.8764	.9095	.0063	.0486	.0486	.0486	0.0000
7	.0196	.0196	.0000	.0000	.0196	13.8764	.9843	.0072	.0086	.0086	.0086	0.0000
8	.7309	.7309	.0000	.0000	.7309	13.8764	.9228	.0072	.0397	.0397	.0397	0.0000
9	.5661	.5661	.0000	.0000	.5661	13.8764	.9336	.0072	.0344	.0344	.0344	0.0000
10	.4195	.4195	.0000	.0000	.4195	13.8764	.9444	.0072	.0285	.0285	.0285	0.0000
11	.2698	.2698	.0000	.0000	.2698	13.8764	.9579	.0072	.0209	.0209	.0209	0.0000
12	.1527	.1527	.0000	.0000	.1527	13.8764	.9742	.0072	.0133	.0133	.0133	0.0000
13	.0197	.0197	.0000	.0000	.0197	13.8764	.9834	.0073	.0084	.0084	.0084	0.0000

TABLE A-4. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 C DIESEL
TEST: 06-02 FUEL: EM-465-F PROJECT: 11-5830-006
BAROMETER 29.04
DATE: 03/20/81

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 500.	0.	.0	.021	2.37	4.5	.902	488.	372.	1.63	340.	37.	56.	83.	1
2	2	INTER / 1400.	18.	2.6	.072	7.13	4.5	.903	448.	399.	2.02	240.	94.	165.	162.	2
3	25	INTER / 1400.	221.	32.4	.150	7.30	4.5	.910	316.	425.	4.40	645.	66.	173.	428.	3
4	50	INTER / 1400.	441.	64.6	.250	7.72	4.5	.919	280.	159.	7.07	1245.	63.	68.	865.	4
5	75	INTER / 1400.	662.	97.0	.357	8.85	4.5	.924	204.	159.	9.09	1710.	52.	75.	1321.	5
6	100	INTER / 1400.	882.	129.3	.488	9.97	4.5	.931	128.	425.	10.96	1785.	38.	228.	1564.	6
7		IDLE / 500.	0.	.0	.018	2.26	4.1	.885	480.	412.	1.59	340.	32.	54.	73.	7
8	100	RATED / 2200.	773.	178.1	.734	18.41	4.1	.917	112.	359.	8.88	1215.	60.	357.	1974.	8
9	75	RATED / 2200.	579.	133.4	.567	16.42	4.1	.912	124.	532.	7.52	900.	60.	482.	1329.	9
10	50	RATED / 2200.	387.	89.1	.416	14.62	4.1	.906	128.	439.	6.21	595.	54.	353.	780.	10
11	25	RATED / 2200.	193.	44.4	.262	12.70	4.1	.898	236.	306.	4.46	380.	86.	215.	436.	11
12	2	RATED / 2200.	15.	3.4	.146	11.49	4.1	.890	472.	425.	2.60	180.	157.	279.	193.	12
13		IDLE / 500.	0.	.0	.021	2.30	4.9	.906	480.	385.	1.59	330.	37.	59.	82.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	28.89	43.75	65.23	******	******	*****	.0090	.0687	.131	.984	.0082	-8.9	.996	*****	.067	1
2	21.71	38.26	37.54	36.17	63.75	62.57	.0101	.0687	.147	.980	.0100	-1.1	1.004	1.661	.080	2
3	7.36	19.17	47.47	2.05	5.34	13.22	.0207	.0687	.301	.960	.0210	1.6	1.004	.277	.080	3
4	4.20	4.51	57.63	.98	1.05	13.39	.0326	.0687	.474	.937	.0330	1.4	1.006	.231	.080	4
5	2.43	3.52	61.71	.54	.78	13.61	.0405	.0687	.590	.921	.0420	3.7	1.010	.218	.080	5
6	1.28	7.79	53.37	.29	1.77	12.10	.0492	.0687	.716	.907	.0502	2.2	1.016	.223	.080	6
7	29.03	49.51	66.66	******	******	*****	.0080	.0687	.117	.984	.0080	-.6	1.001	*****	.067	7
8	1.36	8.12	44.83	.34	2.01	11.08	.0400	.0687	.583	.923	.0411	2.7	1.063	.233	.080	8
9	1.75	14.16	39.08	.45	3.61	9.96	.0347	.0687	.505	.934	.0351	1.4	1.053	.242	.080	9
10	2.16	14.14	31.27	.61	3.96	8.76	.0285	.0687	.416	.944	.0292	2.3	1.043	.269	.080	10
11	5.45	13.68	27.72	1.93	4.85	9.83	.0207	.0687	.302	.959	.0212	2.2	1.033	.343	.080	11
12	17.99	31.89	22.03	45.80	81.20	56.11	.0128	.0687	.186	.975	.0127	-.0	1.027	2.480	.080	12
13	29.08	46.34	64.81	******	******	*****	.0092	.0687	.134	.984	.0080	-13.5	1.001	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC -------- =	1.055	GRAM/KW-HR	(.787	GRAM/BHP-HR)
BSCO -------- =	3.275	GRAM/KW-HR	(2.443	GRAM/BHP-HR)
BSNOX ------- =	11.947	GRAM/KW-HR	(8.913	GRAM/BHP-HR)
BSHC + BSNOX =	13.002	GRAM/KW-HR	(9.700	GRAM/BHP-HR)
CORR. BSFC - =	.261	KG/KW-HR	(.430	LBS/BHP-HR)

TABLE A-4 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 C DIESEL　　BAROMETER 29,04
TEST: 06-02　　FUEL: EM-465-F　　PROJECT:11-5830-006　　DATE: 03/20/81

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	F/A RATIO FUEL CARBON	F/A RATIO EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	,0212	,0212	,0000	,0000	,0212	13,8764	,9840	,0073	,0090	,0090	,0090	0,0000
2	,0718	,0718	,0000	,0000	,0718	13,8764	,9804	,0073	,0101	,0101	,0101	0,0000
3	,1504	,1504	,0000	,0000	,1504	13,8764	,4596	,0073	,0207	,0207	,0207	0,0000
4	,2502	,2502	,0000	,0000	,2502	13,8764	,9374	,0073	,0326	,0326	,0326	0,0000
5	,3568	,3568	,0000	,0000	,3568	13,8764	,9212	,0073	,0405	,0405	,0405	0,0000
6	,4883	,4883	,0000	,0000	,4883	13,8764	,9066	,0073	,0492	,0492	,0492	0,0000
7	,0181	,0181	,0000	,0000	,0181	13,8764	,9843	,0066	,0080	,0080	,0080	0,0000
8	,7339	,7339	,0000	,0000	,7339	13,8764	,9229	,0066	,0400	,0400	,0400	0,0000
9	,5669	,5669	,0000	,0000	,5669	13,8764	,9337	,0066	,0347	,0347	,0347	0,0000
10	,4157	,4157	,0000	,0000	,4157	13,8764	,9444	,0066	,0285	,0285	,0285	0,0000
11	,2623	,2623	,0000	,0000	,2623	13,8764	,9592	,0066	,0207	,0207	,0207	0,0000
12	,1459	,1459	,0000	,0000	,1459	13,8764	,9753	,0066	,0128	,0128	,0128	0,0000
13	,0212	,0212	,0000	,0000	,0212	13,8764	,9843	,0079	,0092	,0092	,0092	0,0000

TABLE A-5. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100C DIESEL + METHANOL   19 BTDC
TEST:01-03   FUEL:EM-465-F   PROJECT:11-5044-001   DATE:09/12/80

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N x M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 530.	0.	.0	.019	2.55	10.5	.987	160.	292.	1.94	588.	9.	33.	110.	1
2	2	INTER / 1400.	19.	2.8	.065	7.00	10.5	.988	360.	706.	2.29	519.	60.	230.	276.	2
3	25	INTER / 1400.	239.	35.0	.262	7.37	10.5	.992	440.	827.	5.38	568.	89.	312.	349.	3
4	50	INTER / 1400.	480.	70.4	.495	8.18	10.5	.995	536.	1839.	7.71	656.	124.	763.	444.	4
5	75	INTER / 1400.	719.	105.4	.784	9.82	10.5	.997	172.	3345.	9.40	617.	49.	1652.	497.	5
6	100	INTER / 1400.	960.	140.8	1.105	11.29	10.5	.999	48.	4542.	10.70	850.	17.	2649.	809.	6
7		IDLE / 530.	0.	.0	.019	2.53	10.5	.987	188.	345.	2.02	578.	10.	38.	103.	7
8	100	RATED / 2200.	819.	188.7	1.553	18.83	10.5	.997	128.	666.	9.09	372.	73.	659.	601.	8
9	75	RATED / 2200.	614.	141.6	1.184	16.55	10.5	.496	244.	372.	8.09	352.	121.	324.	500.	9
10	50	RATED / 2200.	410.	94.4	.823	14.25	10.5	.994	512.	412.	6.80	263.	212.	309.	321.	10
11	25	RATED / 2200.	205.	47.2	.523	12.45	10.5	.992	716.	720.	5.57	202.	244.	455.	208.	11
12	2	RATED / 2200.	16.	3.7	.242	10.46	10.5	.990	848.	1071.	4.19	119.	214.	516.	94.	12
13		IDLE / 530.	0.	.0	.019	2.53	10.5	.987	176.	292.	1.92	568.	10.	34.	107.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	8.23	29.69	97.55	******	******	*****	.0074	.0687	.108	.979	.0094	26.7	1.005	*****	.067	1
2	15.39	59.45	71.31	21.42	82.73	99.23	.0093	.0687	.136	.976	.0114	21.9	1.006	1.383	.080	2
3	5.62	19.81	22.19	2.53	8.91	9.99	.0340	.1040	.346	.929	.0390	8.4	1.006	.447	.080	3
4	4.18	25.65	14.93	1.76	10.83	6.30	.0612	.1230	.498	.886	.0654	6.8	1.010	.418	.080	4
5	1.05	35.13	10.57	.47	15.68	4.72	.0806	.1328	.607	.855	.0853	5.8	1.018	.438	.080	5
6	.25	34.96	12.20	.12	18.82	5.75	.0989	.1383	.715	.833	.1005	1.6	1.029	.458	.080	6
7	9.27	33.59	91.81	******	******	*****	.0075	.0687	.109	.978	.0098	31.5	1.007	*****	.067	7
8	.24	7.07	6.44	.39	3.49	3.18	.0834	.1394	.598	.856	.0842	1.0	1.065	.463	.080	8
9	1.70	4.56	7.03	.85	2.29	3.53	.0723	.1361	.531	.873	.0737	2.0	1.053	.477	.080	9
10	4.30	6.25	6.51	2.25	3.27	3.41	.0583	.1300	.449	.894	.0603	3.4	1.040	.503	.080	10
11	7.77	14.48	6.63	5.17	9.64	4.41	.0425	.1187	.358	.918	.0461	8.7	1.029	.647	.080	11
12	14.71	35.49	6.43	57.03	137.64	24.95	.0223	.0946	.236	.947	.0285	27.5	1.022	3.794	.080	12
13	9.14	29.97	95.11	******	******	*****	.0075	.0687	.109	.979	.0093	24.7	1.004	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

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BSHC -------- =  1.479  GRAM/KW-HR     ( 1.103  GRAM/BHP-HR )
BSCO -------- =  9.586  GRAM/KW-HR     ( 7.151  GRAM/BHP-HR )
BSNOX ------- =  5.262  GRAM/KW-HR     ( 3.926  GRAM/BHP-HR )
BSHC + BSNOX  =  6.741  GRAM/KW-HR     ( 5.029  GRAM/BHP-HR )
CORR. BSFC -  =   .493   KG/KW-HR      (  .811  LBS/BHP-HR  )
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TABLE A-5 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100C DIESEL + METHANOL 19 BTDC
TEST:01-03 FUEL:EM-465-F PROJECT:11-5044-001 DATE:09/12/80

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	F/A RATIO FUEL CARBON	F/A RATIO EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0188	.0188	.0000	.0000	.0188	13.8764	.9791	.0169	.0074	.0074	.0074	17.5000
2	.0646	.0646	.0000	.0000	.0646	13.8764	.9759	.0169	.0093	.0093	.0093	17.2500
3	.2624	.1021	.1603	.0000	.1759	21.2300	.9286	.0169	.0360	.0360	.0241	13.3700
4	.4955	.1018	.3936	.0000	.2830	25.2446	.8863	.0169	.0612	.0612	.0350	9.8800
5	.7833	.1028	.6811	.0000	.4162	27.3483	.8554	.0169	.0806	.0806	.0428	7.2500
6	1.1049	.1038	1.0011	.0000	.5645	28.5332	.8329	.0169	.0989	.0989	.0505	5.2500
7	.0188	.0188	.0000	.0000	.0188	13.8764	.9783	.0169	.0075	.0075	.0075	17.3700
8	1.5533	.1351	1.4182	.0000	.7877	28.7686	.8561	.0169	.0834	.0834	.0423	8.2500
9	1.1842	.1287	1.0555	.0000	.6144	28.0524	.8725	.0169	.0723	.0723	.0375	9.6300
10	.8227	.1242	.6985	.0000	.4456	26.7564	.8944	.0169	.0583	.0583	.0316	11.2500
11	.5233	.1263	.3970	.0000	.3090	24.3503	.9176	.0169	.0425	.0425	.0251	12.7500
12	.2424	.1227	.1196	.0000	.1778	19.2702	.9466	.0169	.0223	.0223	.0164	15.2500
13	.0188	.0188	.0000	.0000	.0188	13.8764	.9794	.0169	.0075	.0075	.0075	17.3700

TABLE A-6. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100C DIESEL + METHANOL 19 BTDC
TEST: 01-04 FUEL: EM-465-F PROJECT: 11-5044-001 DATE: 09/19/80

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 525.	0.	.0	,019	2,62	10,9	1,006	200.	306.	1,68	500.	13.	41.	109.	1
2	2	INTER / 1400.	19.	2.8	,069	6,96	10,9	1,006	356.	720.	2,44	550.	59.	235.	293.	2
3	25	INTER / 1400.	239.	35,0	,237	7,25	10,9	1,005	700.	814.	5,19	595.	136.	299.	356.	3
4	50	INTER / 1400.	477.	70,0	,492	8,11	10,9	1,004	440.	1970.	8,09	625.	98.	782.	405.	4
5	75	INTER / 1400.	716.	105,0	,796	9,82	10,9	1,003	148.	3444.	9,94	710.	41.	1640.	552.	5
6	100	INTER / 1400.	956.	140,2	1,083	11,24	10,9	1,003	44.	4156.	11,32	880.	14.	2266.	783.	6
7		IDLE / 525.	0.	.0	,018	2,53	12,3	1,035	176.	266.	1,68	480.	11.	33.	98.	7
8	100	RATED / 2200.	821.	189,1	1,559	18,76	11,5	1,010	144.	653.	8,90	360.	84.	662.	596.	8
9	75	RATED / 2200.	614.	141,6	1,146	16,24	11,5	1,011	312.	359.	7,80	325.	155.	315.	466.	9
10	50	RATED / 2200.	410.	94,4	,798	14,36	11,5	1,012	504.	465.	6,63	230.	209.	349.	282.	10
11	25	RATED / 2200.	205.	47,2	,473	12,26	11,5	1,013	640.	1153.	5,04	155.	220.	741.	163.	11
12	2	RATED / 2200.	16.	3,7	,151	10,81	11,5	1,014	464.	922.	2,83	225.	131.	509.	203.	12
13		IDLE / 525.	0.	.0	,018	2.53	11,5	1,015	196.	292.	1,68	500.	13.	37.	103.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	11.77	35,69	95,15	******	******	*****	,0074	,0687	,107	,982	,0082	11,8	,999	*****	,067	1
2	14,34	57,04	71,09	21.20	84,32	*****	,0100	,0687	,145	,974	,0121	21,3	1,004	1,473	,080	2
3	9,60	21,04	25,09	3,89	8,53	10,17	,0330	,0994	,332	,933	,0362	9,8	1,005	,404	,080	3
4	3,32	26,50	13,72	1,40	11,17	5,78	,0613	,1217	,503	,882	,0677	10,4	1,009	,418	,080	4
5	,86	34,32	11,54	,39	15,62	5,25	,0820	,1326	,618	,849	,0895	9,2	1,017	,448	,080	5
6	,22	34,85	12,04	,10	16,16	5,58	,0975	,1379	,707	,826	,1049	7,6	1,024	,453	,080	6
7	10,40	31,14	91,68	******	******	*****	,0071	,0687	,103	,981	,0082	15,6	1,004	*****	,067	7
8	,90	7,08	6,37	,45	3,50	3,15	,0841	,1394	,603	,859	,0826	-1,7	1,064	,465	,080	8
9	2,25	4,59	6,78	1.09	2,23	3,29	,0714	,1352	,528	,877	,0709	-,7	1,051	,462	,080	9
10	4,37	7,30	5,89	2.22	3,70	2,99	,0562	,1289	,436	,897	,0584	3,9	1,039	,488	,080	10
11	7,76	26,13	5,73	4,67	15,71	3,45	,0390	,1155	,338	,926	,0412	5,5	1,029	,585	,080	11
12	14,41	55,98	22,29	34,93	135,66	54,02	,0142	,0767	,185	,968	,0157	10,9	1,020	2,376	,080	12
13	11,55	34,09	95,25	******	******	*****	,0072	,0687	,105	,982	,0082	13,8	1,003	*****	,067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- = 1,423 GRAM/KW-HR (1,061 GRAM/BHP-HR)
BSCO ------- = 9,520 GRAM/KW-HR (7,102 GRAM/BHP-HR)
BSNOX ------ = 5,255 GRAM/KW-HR (3,920 GRAM/BHP-HR)
BSHC + BSNOX = 6,678 GRAM/KW-HR (4,982 GRAM/BHP-HR)
CORR. BSFC - = ,478 KG/KW-HR (,787 LBS/BHP-HR)

TABLE A-6 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE:VOLVO TD-100C DIESEL + METHANOL 19 BTDC
TEST:01-04 FUEL: EM-465-F PROJECT:11-5044-001 DATE: 09/19/80

									F/A	RATIO		
MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	MASS FUEL	FUEL CARBON	EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0191	.0191	.0000	.0000	.0191	13,8764	,9817	,0176	,0074	,0074	,0074	18,7500
2	.0686	.0686	.0000	.0000	.0686	13,8764	,9745	,0176	,0100	,0100	,0100	18,0000
3	.2365	.1049	.1317	.0000	.1655	20,2756	,9333	,0176	,0330	,0330	,0231	14,2500
4	.4917	.1061	.3855	.0000	.2836	24,9822	,8822	,0176	,0613	,0613	,0353	10,5000
5	.7964	.1060	.6903	.0000	.4237	27,2877	,8486	,0176	,0820	,0820	,0436	7,6300
6	1.0834	.1045	.9790	.0000	.5550	28,4515	,8258	,0176	,0975	,0975	,0499	5,7500
7	.0178	.0178	.0000	.0000	.0178	13,8764	,9813	,0198	,0071	,0071	,0071	18,7500
8	1.5589	.1356	1.4232	.0000	.7906	28,7668	,8586	,0185	,0841	,0841	,0426	8,5000
9	1.1463	.1317	1.0147	.0000	.5986	27,8550	,8770	,0185	,0714	,0714	,0373	10,2500
10	.7983	.1270	.6713	.0000	.4359	26,5186	,8972	,0185	,0562	,0562	,0307	11,7500
11	.4729	.1280	.3449	.0000	.2867	23,6591	,9258	,0185	,0390	,0390	,0237	13,7500
12	.1515	.1229	.0285	.0000	.1361	15,5347	,9683	,0185	,0142	,0142	,0127	16,7500
13	.0180	.0180	.0000	.0000	.0180	13,8764	,9815	,0185	,0072	,0072	,0072	18,2500

TABLE A-7. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100C DIESEL + METHANOL + CATALYST AT 19 BTDC
TEST:102-01 FUEL: EM-465-F PROJECT:11-5044-001 DATE: 10/02/80

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 532.	0.	.0	.018	2.55	11.4	1.055	14.	45.	1.78	440.	1.	5.	87.	1
2	2	INTER / 1400.	19.	2.8	.072	6.97	11.4	1.051	104.	239.	2.41	550.	19.	85.	320.	2
3	25	INTER / 1400.	247.	36.2	.269	7.61	11.4	1.034	62.	74.	5.65	625.	13.	28.	385.	3
4	50	INTER / 1400.	495.	72.6	.504	8.43	11.4	1.021	36.	93.	7.99	745.	9.	39.	514.	4
5	75	INTER / 1400.	742.	108.8	.783	9.90	11.4	1.012	22.	119.	9.94	845.	6.	58.	670.	5
6	100	INTER / 1400.	990.	145.2	1.117	11.60	11.4	1.004	10.	133.	11.44	935.	3.	76.	877.	6
7		IDLE / 530.	0.	.0	.018	2.51	11.4	1.055	12.	66.	1.73	440.	1.	8.	91.	7
8	100	RATED / 2200.	827.	190.6	1.578	19.20	11.4	1.013	13.	66.	9.23	620.	8.	66.	1009.	8
9	75	RATED / 2200.	620.	142.8	1.145	16.34	11.4	1.019	27.	58.	8.09	480.	13.	49.	668.	9
10	50	RATED / 2200.	414.	95.3	.800	14.46	11.4	1.026	36.	106.	6.89	350.	15.	78.	422.	10
11	25	RATED / 2200.	206.	47.5	.480	12.42	11.4	1.035	43.	106.	5.34	285.	15.	68.	298.	11
12	2	RATED / 2200.	16.	3.7	.182	10.86	11.4	1.046	60.	127.	3.30	270.	17.	70.	244.	12
13		IDLE / 530.	0.	.0	.018	2.50	11.4	1.055	38.	119.	1.57	335.	3.	16.	74.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	.80	5.09	81.15	******	******	*****	.0071	.0687	.103	.981	.0085	20.1	.991	*****	.067	1
2	4.36	19.74	74.11	6.76	30.57	*****	.0104	.0687	.152	.975	.0116	11.1	.997	1.553	.080	2
3	.77	1.73	23.82	.35	.77	10.64	.0358	.1037	.345	.926	.0399	11.3	.998	.448	.080	3
4	.28	1.30	16.99	.12	.54	7.08	.0605	.1220	.496	.885	.0651	7.6	1.000	.416	.080	4
5	.13	1.23	14.28	.06	.53	6.16	.0800	.1320	.606	.852	.0861	7.6	1.008	.428	.080	5
6	.05	1.14	13.08	.02	.53	6.04	.0974	.1382	.704	.827	.1023	5.0	1.017	.454	.080	6
7	.70	7.67	83.40	******	******	*****	.0073	.0687	.107	.981	.0083	12.8	1.001	*****	.067	7
8	.08	.70	10.66	.04	.35	5.29	.0831	.1394	.596	.855	.0847	1.9	1.056	.470	.080	8
9	.19	.72	9.73	.09	.35	4.68	.0709	.1352	.524	.873	.0727	2.6	1.043	.461	.080	9
10	.31	1.63	8.79	.15	.82	4.43	.0560	.1282	.437	.894	.0594	6.1	1.032	.489	.080	10
11	.51	2.36	10.34	.31	1.43	6.27	.0391	.1148	.341	.923	.0418	7.0	1.021	.594	.080	11
12	1.57	6.46	22.39	4.56	18.76	65.09	.0169	.0819	.207	.962	.0187	10.5	1.013	2.869	.080	12
13	2.44	15.15	69.59	******	******	*****	.0072	.0687	.105	.983	.0075	4.6	.997	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC -------- = .142 GRAM/KW-HR (.106 GRAM/BHP-HR)
BSCO -------- = .761 GRAM/KW-HR (.568 GRAM/BHP-HR)
BSNOX ------- = 6.645 GRAM/KW-HR (4.957 GRAM/BHP-HR)
BSHC + BSNOX = 6.787 GRAM/KW-HR (5.063 GRAM/BHP-HR)
CORR. BSFC - = .481 KG/KW-HR (.792 LBS/BHP-HR)

TABLE A-7 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100C DIESEL + METHANOL + CATALYST AT 19 BTDC DATE: 10/02/80
TEST:02-01 FUEL: EM-465-F PROJECT:11-5044-001

MODE	TOTAL FUEL KG/MIN	DIESFL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESFL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A MASS FUEL	RATIO FUEL CARBON	EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0178	.0178	.0000	.0000	.0178	13.8764	.9806	.0183	.0071	.0071	.0071	18.6300
2	.0719	.0719	.0000	.0000	.0719	13.8764	.9751	.0183	.0104	.0104	.0104	17.6300
3	.2694	.1057	.1637	.0000	.1810	21.1714	.9259	.0183	.0358	.0358	.0241	13.2500
4	.5041	.1076	.3965	.0000	.2901	25.0441	.8848	.0183	.0605	.0605	.0348	9.8750
5	.7828	.1070	.6757	.0000	.4180	27.1782	.8519	.0183	.0800	.0800	.0427	7.2500
6	1.1167	.1055	1.0111	.0000	.5708	28.5159	.8274	.0183	.0974	.0974	.0498	5.0750
7	.0181	.0181	.0000	.0000	.0181	13.8764	.9812	.0183	.0073	.0073	.0073	17.6250
8	1.5776	.1371	1.4405	.0000	.8000	28.7702	.8546	.0183	.0831	.0831	.0421	8.2500
9	1.1449	.1316	1.0134	.0000	.5979	27.8523	.8734	.0183	.0709	.0709	.0370	9.8750
10	.8005	.1319	.6686	.0000	.4396	26.3560	.8945	.0183	.0560	.0560	.0308	11.2500
11	.4803	.1328	.3475	.0000	.2927	23.5251	.9233	.0183	.0391	.0391	.0238	13.1250
12	.1817	.1290	.0527	.0000	.1532	16.6052	.9624	.0183	.0169	.0169	.0143	15.7500
13	.0178	.0178	.0000	.0000	.0178	13.8764	.9829	.0183	.0072	.0072	.0072	17.8750

TABLE A-8. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100C DIESEL + METHANOL + CATALYST AT 19 BTDC
TEST:02-02 FUEL: EM-465-F PROJECT:11-5044-001 DATE: 10/02/80

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 530.	0.	.0	.018	2.49	10.0	1.004	16.	34.	1.68	360.	1.	4.	77.	1
2	2	INTER / 1400.	19.	2.8	.072	6.90	10.0	1.003	108.	266.	2.44	560.	19.	94.	322.	2
3	25	INTER / 1400.	247.	36.2	.266	7.53	10.0	.998	76.	74.	5.41	650.	16.	29.	413.	3
4	50	INTER / 1400.	495.	72.6	.519	8.37	10.0	.994	38.	114.	7.54	790.	10.	54.	589.	4
5	75	INTER / 1400.	742.	108.8	.802	9.88	10.0	.991	20.	133.	9.79	870.	6.	67.	717.	5
6	100	INTER / 1400.	990.	145.2	1.113	11.44	10.0	.989	12.	125.	11.00	960.	4.	75.	935.	6
7		IDLE / 530.	0.	.0	.018	2.43	10.0	1.004	9.	34.	1.68	440.	1.	4.	92.	7
8	100	RATED / 2200.	827.	190.6	1.572	18.94	10.0	.992	16.	80.	9.15	620.	9.	80.	1016.	8
9	75	RATED / 2200.	620.	142.8	1.151	16.21	10.0	.993	28.	85.	7.99	440.	14.	74.	695.	9
10	50	RATED / 2200.	414.	95.3	.812	14.27	10.0	.995	41.	106.	6.89	355.	17.	79.	433.	10
11	25	RATED / 2200.	206.	47.5	.473	12.30	10.0	.998	56.	159.	5.26	290.	19.	102.	305.	11
12	2	RATED / 2200.	16.	3.7	.182	10.71	10.0	1.001	72.	138.	3.18	245.	21.	79.	229.	12
13		IDLE / 530.	0.	.0	.020	2.46	10.0	1.003	41.	106.	1.62	320.	3.	15.	76.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	.97	4.07	70.37	******	******	*****	.0074	.0687	.107	.982	.0080	8.8	.995	*****	.067	1
2	4.47	21.67	74.45	6.95	33.69	*****	.0106	.0687	.154	.975	.0117	11.2	1.001	1.552	.080	2
3	.99	1.80	25.84	.44	.80	11.42	.0357	.1038	.344	.929	.0383	7.1	1.002	.441	.080	3
4	.31	1.75	18.90	.13	.75	8.11	.0626	.1231	.509	.890	.0622	-.7	1.005	.427	.080	4
5	.12	1.40	14.89	.05	.62	6.59	.0820	.1323	.620	.854	.0850	3.7	1.013	.437	.080	5
6	.06	1.12	14.00	.03	.51	6.44	.0982	.1380	.712	.833	.0985	.3	1.025	.449	.080	6
7	.54	4.08	86.05	******	******	*****	.0074	.0687	.108	.982	.0080	8.1	1.009	*****	.067	7
8	.10	.85	10.77	.05	.42	5.33	.0838	.1392	.602	.856	.0839	.1	1.062	.466	.080	8
9	.20	1.07	10.06	.10	.52	4.87	.0717	.1350	.531	.875	.0718	.1	1.047	.462	.080	9
10	.35	1.63	8.89	.18	.83	4.54	.0575	.1286	.447	.895	.0596	3.7	1.037	.493	.080	10
11	.68	3.61	10.73	.41	2.15	6.41	.0388	.1142	.340	.925	.0410	5.7	1.026	.582	.080	11
12	1.94	7.24	20.98	5.66	21.10	61.13	.0172	.0822	.209	.964	.0181	5.5	1.017	2.864	.080	12
13	2.55	13.09	64.48	******	******	*****	.0080	.0687	.117	.983	.0078	-3.3	.999	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

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BSHC -------- =      .165  GRAM/KW-HR      (  .123  GRAM/BHP-HR )
BSCO -------- =      .892  GRAM/KW-HR      (  .665  GRAM/BHP-HR )
BSNOX ------- =     6.929  GRAM/KW-HR      ( 5.169  GRAM/BHP-HR )
BSHC + BSNOX =      7.094  GRAM/KW-HR      ( 5.292  GRAM/BHP-HR )
CORR. BSFC - =       .481   KG/KW-HR       (  .791  LBS/BHP-HR  )
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TABLE A-8 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100C DIESEL + METHANOL + CATALYST AT 19 BTDC
TEST:02-02 FUEL: EM-465-F PROJECT:11-5044-001 DATE: 10/02/80

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A MASS FUEL	RATIO FUEL CARBON	EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0181	.0181	.0000	.0000	.0181	13,8764	,9822	,0160	,0074	,0074	,0074	19,1250
2	.0721	.0721	.0000	.0000	.0721	13,8764	,9752	,0160	,0106	,0106	,0106	18,0000
3	.2665	.1043	.1622	.0000	.1789	21,1885	,9291	,0160	,0357	,0357	,0240	13,7500
4	.5192	.1061	.4131	.0000	.2962	25,2805	,8901	,0160	,0626	,0626	,0357	9,8750
5	.8024	.1083	.6941	.0000	.4277	27,2318	,8540	,0160	,0820	,0820	,0437	7,3750
6	1.1131	.1070	1.0060	.0000	.5700	28,4603	,8335	,0160	,0982	,0982	,0503	5,1250
7	.0128	.0178	.0000	.0000	.0178	13,8764	,9822	,0160	,0074	,0074	,0074	18,1200
8	1.5716	.1389	1.4327	.0000	.7982	28,7201	,8562	,0160	,0838	,0838	,0426	8,2500
9	1.1513	.1335	1.0178	.0000	.6019	27,8197	,8751	,0160	,0717	,0717	,0375	9,8750
10	.8121	.1313	.6807	.0000	.4446	26,4441	,8946	,0160	,0575	,0575	,0315	11,2500
11	.4729	.1337	.3392	.0000	.2898	23,3855	,9250	,0160	,0388	,0388	,0238	13,2500
12	.1821	.1282	.0539	.0000	.1530	16,6740	,9640	,0160	,0172	,0172	,0144	16,0000
13	.0196	.0196	.0000	.0000	.0196	13,8764	,9829	,0160	,0080	,0080	,0080	18,0000

TABLE A-9. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 A DIESEL+ETHANOL AT 19 BTDC
TEST:03-01 FUEL: EM-465-F PROJECT:11-5830-006 DATE: 10/17/80

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 510.	0.	.0	.018	2.35	12.6	1.063	176.	292.	1.61	530.	12.	39.	116.	1
2	2	INTER / 1400.	18.	2.6	.074	6.86	12.6	1.060	308.	696.	2.47	575.	55.	242.	327.	2
3	25	INTER / 1400.	232.	34.0	.198	7.14	12.6	1.047	936.	837.	5.09	630.	180.	306.	375.	3
4	50	INTER / 1400.	464.	68.0	.407	8.18	12.6	1.034	752.	2792.	7.90	700.	173.	1173.	480.	4
5	75	INTER / 1400.	696.	102.0	.596	9.59	12.6	1.026	168.	3881.	9.72	870.	45.	1863.	681.	5
6	100	INTER / 1400.	929.	136.2	.825	11.08	12.6	1.019	24.	2349.	11.32	920.	8.	1327.	848.	6
7		IDLE / 510.	0.	.0	.020	2.35	12.6	1.062	184.	279.	1.81	540.	12.	36.	115.	7
8	100	RATED / 2200.	803.	185.0	1.196	18.71	12.6	1.027	56.	706.	9.34	620.	31.	703.	1007.	8
9	75	RATED / 2200.	602.	138.7	.934	16.73	12.6	1.032	184.	639.	8.28	445.	90.	567.	644.	9
10	50	RATED / 2200.	401.	92.5	.656	14.35	12.6	1.038	504.	800.	7.12	310.	204.	596.	377.	10
11	25	RATED / 2200.	201.	46.2	.438	12.66	12.6	1.044	992.	1597.	5.57	230.	345.	1041.	245.	11
12	2	RATED / 2200.	18.	4.1	.198	10.94	12.6	1.055	832.	1208.	3.30	230.	249.	703.	218.	12
13		IDLE / 510.	0.	.0	.019	2.35	12.6	1.063	208.	266.	1.68	480.	14.	35.	103.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	GRAMS/KW-HR HC	GRAMS/KW-HR CO	GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	10.81	35.57	*****	******	******	*****	.0079	.0687	.115	.982	.0079	-.6	1.017	*****	.067	1
2	12.30	54.65	73.66	21.11	93.78	*****	.0109	.0687	.159	.974	.0122	11.6	1.024	1.676	.080	2
3	15.17	25.78	31.66	5.29	8.99	11.04	.0280	.0845	.331	.942	.0306	9.0	1.021	.341	.080	3
4	7.10	48.03	19.65	2.55	17.25	7.06	.0504	.0960	.525	.902	.0536	6.4	1.026	.350	.080	4
5	1.27	52.11	19.06	.45	18.26	6.68	.0629	.1001	.629	.878	.0677	7.6	1.031	.340	.080	5
6	.16	26.80	17.12	.06	9.74	6.22	.0754	.1030	.732	.860	.0787	4.3	1.043	.348	.080	6
7	10.11	30.34	95.80	******	******	*****	.0086	.0687	.126	.980	.0088	2.0	1.021	*****	.067	7
8	.44	9.80	14.04	.17	3.80	5.45	.0647	.1038	.623	.881	.0654	1.1	1.078	.360	.080	8
9	1.62	10.13	11.50	.65	4.09	4.64	.0565	.1025	.551	.894	.0578	2.2	1.066	.379	.080	9
10	5.20	15.14	9.57	2.21	6.44	4.07	.0463	.0991	.467	.910	.0488	5.4	1.050	.405	.080	10
11	13.12	39.63	9.31	7.45	22.52	5.29	.0350	.0943	.372	.930	.0377	7.6	1.040	.546	.080	11
12	21.03	59.29	18.42	61.39	173.06	53.76	.0183	.0800	.229	.962	.0194	6.0	1.030	2.834	.080	12
13	12.27	31.08	91.51	******	******	*****	.0081	.0687	.117	.982	.0082	1.9	1.016	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

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BSHC --------- =  1.746  GRAM/KW-HR    ( 1.302  GRAM/BHP-HR )
BSCO --------- = 10.643  GRAM/KW-HR    ( 7.939  GRAM/BHP-HR )
BSNOX -------- =  6.773  GRAM/KW-HR    ( 5.053  GRAM/BHP-HR )
BSHC + BSNOX  =  8.519  GRAM/KW-HR    ( 6.355  GRAM/BHP-HR )
CORR. BSFC - =   .392  KG/KW-HR      (  .646  LBS/BHP-HR  )
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TABLE A-9 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 A DIESEL+ETHANOL AT 19 BTDC
TEST:03-01 FUEL: EM-465-F PROJECT:11-5830-006 DATE: 10/17/80

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	FUEL CARBON	EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0184	.0184	.0000	.0000	.0184	13.8764	.9823	.0203	.0079	.0079	.0079	18.6250
2	.0739	.0739	.0000	.0000	.0739	13.8764	.9740	.0203	.0109	.0109	.0109	18.0000
3	.1975	.1005	.0971	.0000	.1617	17.2459	.9416	.0203	.0280	.0280	.0229	15.2500
4	.4020	.1041	.3029	.0000	.2952	19.7085	.9024	.0203	.0504	.0504	.0365	10.0000
5	.5959	.1066	.4892	.0000	.4153	20.6021	.8784	.0203	.0629	.0629	.0438	7.3750
6	.8251	.1062	.7199	.0000	.5594	21.2467	.8597	.0203	.0754	.0754	.0511	5.0000
7	.0200	.0200	.0000	.0000	.0200	13.8764	.9804	.0203	.0086	.0086	.0086	18.0000
8	1.1955	.1358	1.0597	.0000	.8044	21.4287	.8811	.0203	.0647	.0647	.0435	8.3750
9	.9336	.1270	.8066	.0000	.6359	21.1374	.8941	.0203	.0565	.0565	.0385	9.8750
10	.6560	.1284	.5276	.0000	.4613	20.3999	.9097	.0203	.0463	.0463	.0326	11.6250
11	.4379	.1266	.3113	.0000	.3230	19.3436	.9298	.0203	.0350	.0350	.0258	13.5000
12	.1976	.1244	.0732	.0000	.1706	16.2733	.9618	.0203	.0183	.0183	.0158	16.5000
13	.0187	.0187	.0000	.0000	.0187	13.8764	.9816	.0203	.0081	.0081	.0081	18.8750

TABLE A-10. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 A DIESEL+ETHANOL AT 19 BTDC
TEST:03-02 FUEL: EM-465-F PROJECT:11-5830-006 DATE: 10/22/80

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 510.	0.	.0	.019	2.41	8.1	.964	208.	279.	1.63	520.	14.	37.	114.	1
2	2	INTER / 1400.	18.	2.6	.076	7.02	8.1	.965	312.	693.	2.42	625.	58.	253.	372.	2
3	25	INTER / 1400.	232.	34.0	.198	7.31	8.1	.966	944.	841.	5.11	635.	180.	306.	377.	3
4	50	INTER / 1400.	464.	68.0	.394	8.37	8.1	.967	784.	2300.	7.71	725.	181.	970.	499.	4
5	75	INTER / 1400.	696.	102.0	.586	9.84	8.1	.968	240.	3645.	9.40	865.	66.	1782.	690.	5
6	100	INTER / 1400.	936.	137.2	.834	11.50	8.1	.969	52.	2475.	11.13	920.	17.	1436.	871.	6
7		IDLE / 510.	0.	.0	.018	2.36	8.1	.964	184.	271.	1.83	540.	11.	32.	103.	7
8	100	RATED / 2200.	807.	186.0	1.203	19.18	8.1	.968	48.	720.	9.30	640.	27.	723.	1049.	8
9	75	RATED / 2200.	604.	139.1	.909	16.75	8.1	.967	180.	618.	8.14	440.	88.	546.	634.	9
10	50	RATED / 2200.	402.	92.6	.670	14.75	8.1	.967	384.	814.	7.07	320.	160.	624.	400.	10
11	25	RATED / 2200.	201.	46.3	.425	12.81	8.1	.966	768.	1555.	5.49	220.	265.	1011.	233.	11
12	2	RATED / 2200.	18.	4.1	.191	11.13	8.1	.965	608.	1208.	3.30	230.	180.	694.	216.	12
13		IDLE / 2200.	0.	.0	.019	2.36	8.1	.964	184.	266.	1.68	510.	12.	35.	111.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	12.60	33.55	*****	******	******	*****	.0077	.0687	.113	.983	.0080	3.0	.992	*****	.067	1
2	12.69	55.49	81.65	22.36	97.82	*****	.0109	.0687	.159	.976	.0120	9.5	.997	1.768	.080	2
3	15.22	25.80	31.79	5.30	8.99	11.08	.0272	.0845	.322	.942	.0307	12.7	.998	.349	.080	3
4	7.65	41.09	21.13	2.66	14.27	7.34	.0474	.0952	.498	.906	.0517	9.0	1.002	.347	.080	4
5	1.87	50.73	19.64	.65	17.47	6.76	.0600	.0998	.601	.883	.0655	9.1	1.010	.341	.080	5
6	.35	28.71	17.41	.13	10.46	6.35	.0731	.1029	.710	.863	.0775	6.0	1.016	.359	.080	6
7	10.00	29.17	94.82	******	******	*****	.0077	.0687	.113	.981	.0089	15.2	1.000	*****	.067	7
8	.37	10.02	14.53	.15	3.89	5.64	.0632	.1041	.608	.882	.0653	3.2	1.056	.368	.080	8
9	1.61	10.00	11.62	.63	3.92	4.56	.0547	.1021	.536	.897	.0566	3.4	1.040	.377	.080	9
10	3.98	15.52	9.95	1.73	6.74	4.32	.0458	.0993	.461	.911	.0485	5.9	1.030	.422	.080	10
11	10.41	39.65	9.15	5.74	21.85	5.04	.0334	.0935	.357	.932	.0367	9.8	1.020	.540	.080	11
12	15.65	60.48	18.79	44.21	170.82	53.06	.0173	.0790	.219	.963	.0190	9.7	1.012	2.791	.080	12
13	10.85	31.13	97.37	******	******	*****	.0081	.0687	.118	.983	.0082	1.2	.993	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- =	1.544 GRAM/KW-HR	(1.152	GRAM/BHP-HR)
BSCO ------- =	10.387 GRAM/KW-HR	(7.749	GRAM/BHP-HR)
BSNOX ------ =	6.917 GRAM/KW-HR	(5.160	GRAM/BHP-HR)
BSHC + BSNOX =	8.461 GRAM/KW-HR	(6.312	GRAM/BHP-HR)
CORR. BSFC - =	.398 KG/KW-HR	(.654	LBS/BHP-HR)

TABLE A-10 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 A DIESEL+ETHANOL AT 19 BTDC
TEST:03-02 FUEL: EM-465-F PROJECT:11-5830-006 DATE: 10/22/80

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	F/A RATIO FUEL CARBON	F/A RATIO EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0186	.0186	.0000	.0000	.0186	13.8764	.9831	.0130	.0077	.0077	.0077	18.6300
2	.0760	.0760	.0000	.0000	.0760	13.8764	.9756	.0130	.0109	.0109	.0109	17.7500
3	.1975	.1005	.0971	.0000	.1617	17.2459	.9425	.0130	.0272	.0272	.0223	14.2500
4	.3936	.1067	.2869	.0000	.2877	19.5383	.9065	.0130	.0474	.0474	.0347	10.2500
5	.5855	.1070	.4785	.0000	.4089	20.5559	.8832	.0130	.0600	.0600	.0419	7.7500
6	.8335	.1083	.7252	.0000	.5659	21.2152	.8627	.0130	.0731	.0731	.0496	5.2500
7	.0181	.0181	.0000	.0000	.0181	13.8764	.9810	.0130	.0077	.0077	.0077	17.5000
8	1.2034	.1324	1.0710	.0000	.8081	21.4760	.8823	.0130	.0632	.0632	.0425	8.3800
9	.9094	.1301	.7793	.0000	.6218	21.0484	.8970	.0130	.0547	.0547	.0374	9.8800
10	.6698	.1294	.5404	.0000	.4703	20.4303	.9111	.0130	.0458	.0458	.0321	11.2500
11	.4249	.1293	.2957	.0000	.3158	19.1835	.9322	.0130	.0334	.0334	.0249	13.1300
12	.1913	.1258	.0654	.0000	.1671	16.0611	.9633	.0130	.0173	.0173	.0151	16.2500
13	.0190	.0190	.0000	.0000	.0190	13.8764	.9826	.0130	.0081	.0081	.0081	18.5000

TABLE A-11. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD 100 A DIESEL + ETHANOL + CATALYST AT 19 BTDC
TEST: 04-01 FUEL: EM-466-FETH PROJECT:11-5830-006 DATE: 11/06/80

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 600.	0.	.0	.029	1.81	7.4	.933	62.	180.	3.36	630.	3.	19.	108.	1
2	2	INTER / 1400.	27.	4.0	.072	7.01	7.4	.927	180.	425.	2.39	635.	33.	152.	371.	2
3	25	INTER / 1400.	237.	34.8	.219	7.44	7.4	.940	448.	399.	5.19	660.	95.	161.	433.	3
4	50	INTER / 1400.	475.	69.6	.402	8.34	7.4	.950	264.	804.	7.25	825.	67.	377.	632.	4
5	75	INTER / 1400.	712.	104.4	.591	9.60	7.1	.954	88.	1098.	9.44	1020.	24.	526.	797.	5
6	100	INTER / 1400.	949.	134.2	.832	11.32	7.1	.962	24.	532.	11.44	1065.	8.	304.	993.	6
7		IDLE / 500.	0.	.0	.029	1.80	7.1	.925	60.	173.	3.67	675.	3.	17.	106.	7
8	100	RATED / 2200.	814.	187.5	1.209	18.95	7.1	.954	16.	133.	9.40	735.	9.	134.	1207.	8
9	75	RATED / 2200.	610.	140.6	.914	16.68	7.1	.948	68.	146.	8.28	550.	33.	129.	790.	9
10	50	RATED / 2200.	407.	93.7	.670	14.82	7.1	.942	156.	239.	7.16	390.	65.	184.	440.	10
11	25	RATED / 2200.	204.	46.9	.405	12.57	7.1	.939	312.	385.	5.49	308.	107.	249.	325.	11
12	2	RATED / 2200.	18.	4.1	.113	10.97	7.1	.921	160.	306.	2.44	285.	52.	195.	296.	12
13		IDLE / 500.	0.	.0	.030	1.73	7.1	.926	108.	199.	3.30	225.	6.	21.	127.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	1.89	10.74	61.32	******	******	*****	.0163	.0687	.238	.968	.0160	-2.3	1.004	*****	.067	1
2	7.52	35.01	85.74	8.22	38.25	93.25	.0104	.0687	.152	.976	.0116	11.5	1.009	1.083	.080	2
3	7.20	12.20	32.92	2.72	4.61	12.45	.0297	.0851	.349	.942	.0307	3.4	1.009	.375	.080	3
4	2.74	15.65	26.20	.97	5.42	9.08	.0486	.0953	.510	.913	.0475	-2.2	1.013	.342	.080	4
5	.67	14.82	22.47	.23	5.04	7.63	.0621	.1002	.619	.879	.0672	8.2	1.020	.333	.080	5
6	.16	6.09	19.90	.06	2.18	7.14	.0740	.1032	.717	.861	.0782	5.8	1.028	.349	.080	6
7	1.68	9.46	60.20	******	******	*****	.0164	.0687	.239	.965	.0174	6.0	1.010	*****	.067	7
8	.12	1.85	16.64	.05	.71	6.44	.0643	.1039	.618	.882	.0654	1.8	1.070	.362	.080	8
9	.60	2.35	14.41	.24	.91	5.62	.0552	.1019	.541	.896	.0520	3.3	1.056	.369	.080	9
10	1.62	4.57	12.17	.20	1.96	5.22	.0456	.0988	.461	.911	.0483	5.9	1.044	.411	.080	10
11	4.40	10.24	13.75	2.29	5.31	6.93	.0325	.0925	.351	.934	.0352	8.4	1.032	.501	.080	11
12	6.47	24.38	37.05	12.21	47.88	72.76	.0122	.0699	.175	.976	.0120	-1.7	1.024	1.918	.080	12
13	3.45	12.06	21.63	******	******	*****	.0166	.0687	.241	.969	.0157	-5.1	1.009	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC -------- = .609 GRAM/KW-HR (.455 GRAM/BHP-HR)
BSCO -------- = 2.980 GRAM/KW-HR (2.223 GRAM/BHP-HR)
BSNOX ------- = 8.025 GRAM/KW-HR (5.987 GRAM/BHP-HR)
BSHC + BSNOX = 8.635 GRAM/KW-HR (6.441 GRAM/BHP-HR)
CORR. BSFC - = .386 KG/KW-HR (.635 LBS/BHP-HR)

TABLE A-11 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD 100 A DIESEL + ETHANOL + CATALYST AT 19 BTDC
TEST: 04-01 FUEL: EM-466-F ETH PROJECT:11-5830-006 DATE: 11/06/80

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A MASS FUEL	RATIO FUEL CARBON	EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0293	.0293	.0000	.0000	.0293	13.8764	.9681	.0119	.0163	.0163	.0163	16.8800
2	.0724	.0724	.0000	.0000	.0724	13.8764	.9762	.0119	.0104	.0104	.0104	18.2500
3	.2194	.1086	.1109	.0000	.1785	17.3649	.9419	.0119	.0297	.0297	.0242	14.2500
4	.4021	.1083	.2938	.0000	.2936	19.5596	.9128	.0119	.0486	.0486	.0355	10.0100
5	.5311	.1045	.4267	.0000	.4116	20.6280	.8793	.0115	.0621	.0621	.0432	7.1300
6	.8320	.1040	.7280	.0000	.5633	21.2804	.8608	.0115	.0740	.0740	.0501	4.7500
7	.0293	.0293	.0000	.0000	.0293	13.8764	.9653	.0115	.0164	.0164	.0164	17.0000
8	1.2088	.1355	1.0733	.0000	.8127	21.4483	.8820	.0115	.0643	.0643	.0432	8.2500
9	.9149	.1347	.7802	.0000	.6259	21.0067	.8962	.0115	.0552	.0552	.0378	10.0100
10	.6802	.1346	.5456	.0000	.4728	20.3360	.9112	.0115	.0456	.0456	.0321	11.3700
11	.4054	.1319	.2735	.0000	.3045	18.9633	.9340	.0115	.0325	.0325	.0244	13.3700
12	.1330	.1268	.0062	.0000	.1307	14.1374	.9757	.0115	.0122	.0122	.0120	17.6200
13	.0295	.0295	.0000	.0000	.0295	13.8764	.9687	.0115	.0166	.0166	.0166	16.8800

TABLE A-12. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD 100 A   DIESEL + ETHANOL + CATALYST AT 19 BTDC
TEST: 94-02   FUEL: EM-466-FETH PROJECT: 11-5830-006   DATE: 11/07/80

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 500.	0.	.0	.028	1.84	9.6	.975	80.	186.	3.40	610.	4.	18.	97.	1
2	2	INTER / 1900.	16.	2.6	.070	6.83	9.6	.974	152.	372.	2.39	565.	27.	130.	122.	2
3	25	INTER / 1900.	233.	34.2	.230	7.29	9.6	.974	448.	479.	5.80	680.	88.	177.	411.	3
4	50	INTER / 1900.	466.	68.6	.414	8.11	9.6	.983	272.	774.	8.18	800.	64.	324.	555.	4
5	75	INTER / 1900.	701.	102.8	.620	9.58	9.6	.986	76.	1030.	10.27	915.	21.	500.	725.	5
6	100	INTER / 1900.	936.	137.2	.830	11.15	9.6	.987	32.	720.	11.56	1080.	10.	406.	943.	6
7		IDLE / 500.	0.	.0	.028	1.83	9.6	.975	68.	186.	3.80	650.	3.	17.	94.	7
8	100	RATED / 2200.	814.	187.5	1.213	18.84	9.6	.985	16.	154.	9.40	710.	9.	160.	1169.	8
9	75	RATED / 2200.	610.	140.6	.942	16.69	9.6	.983	40.	186.	8.38	555.	20.	167.	811.	9
10	50	RATED / 2200.	407.	93.7	.738	14.76	9.6	.982	108.	212.	7.34	410.	48.	174.	547.	10
11	25	RATED / 2200.	203.	46.9	.507	13.24	9.6	.980	224.	345.	5.41	325.	94.	274.	421.	11
12	2	RATED / 2200.	16.	3.7	.244	11.06	9.6	.976	296.	425.	3.92	280.	93.	258.	277.	12
13		IDLE / 500.	0.	.0	.030	1.84	9.6	.976	96.	212.	3.36	580.	5.	22.	100.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	2.41	10.96	58.63	******	******	*****	.0152	.0687	.221	.967	.0162	6.4	1.008	*****	.067	1
2	6.38	30.74	26.17	10.41	50.20	*****	.0104	.0687	.151	.976	.0116	11.3	1.011	1.616	.080	2
3	6.38	12.87	23.81	2.57	5.18	12.01	.0318	.0866	.367	.934	.0348	9.5	1.011	.398	.080	3
4	2.56	13.26	22.36	.93	4.80	8.09	.0515	.0961	.536	.902	.0536	4.2	1.015	.356	.080	4
5	.56	13.46	19.50	.20	4.82	7.05	.0653	.1003	.651	.875	.0693	6.0	1.021	.354	.080	5
6	.21	8.15	19.94	.18	2.96	7.24	.0751	.1032	.728	.859	.0791	5.3	1.030	.353	.080	6
7	1.85	9.82	55.92	******	******	*****	.0155	.0687	.225	.963	.0180	16.4	1.010	*****	.067	7
8	.12	2.21	16.02	.05	.86	6.23	.0650	.1039	.625	.881	.0654	.7	1.078	.360	.080	8
9	.35	2.95	14.35	.14	1.18	5.76	.0569	.1021	.558	.894	.0577	1.4	1.062	.378	.080	9
10	1.09	3.92	12.76	.51	1.85	5.84	.0505	.0999	.506	.908	.0499	-1.2	1.047	.451	.080	10
11	3.11	9.01	13.85	2.02	5.84	8.98	.0386	.0955	.404	.933	.0358	-7.4	1.044	.621	.080	11
12	6.35	12.60	19.91	29.80	68.69	73.84	.0223	.0831	.268	.955	.0229	2.7	1.034	3.774	.080	12
13	2.93	12.62	56.31	******	******	*****	.0163	.0687	.238	.968	.0160	-1.9	1.011	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

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BSHC -------- =   .593  GRAM/KW-HR    (  .442  GRAM/BHP-HR )
BSCO -------- =  3.206  GRAM/KW-HR    ( 2.391  GRAM/BHP-HR )
BSNOX ------- =  7.916  GRAM/KW-HR    ( 5.906  GRAM/BHP-HR )
BSHC + BSNOx  =  8.509  GRAM/KW-HR    ( 6.348  GRAM/BHP-HR )
CORR. BSFC -  =   .412   KG/KW-HR     (  .678  LBS/BHP-HR  )
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TABLE A-12 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD 100 A   DIESEL + ETHANOL + CATALYST AT 19 BTDC
TEST: 04-02   FUEL: EM-466-FETH PROJECT:11-5830-006   DATE: 11/07/80

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWFT FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	F/A RATIO FUEL CARBON	F/A RATIO EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0222	.0222	.0000	.0000	.0222	13,8264	,9620	,0154	,0152	,0152	,0152	14,1200
2	.0204	.0204	.0000	.0000	.0204	13,8264	,9757	,0154	,0104	,0104	,0104	20,7500
3	.2296	.1053	.1243	.0000	.1837	17,6838	,9341	,0154	,0318	,0318	,0255	15,3700
4	.4136	.1049	.3087	.0000	.2992	19,7326	,9016	,0154	,0515	,0515	,0373	11,3700
5	.6195	.1082	.5113	.0000	.4308	20,6538	,8753	,0154	,0653	,0653	,0454	8,0000
6	.8402	.1138	.7264	.0000	.5621	21,2800	,8589	,0154	,0751	,0751	,0509	5,7500
7	.0281	.0281	.0000	.0000	.0281	13,8264	,9634	,0154	,0155	,0155	,0155	17,7500
8	1.2125	.1360	1.0765	.0000	.8152	21,4472	,8815	,0154	,0650	,0650	,0437	8,1300
9	.9417	.1352	.8065	.0000	.6440	21,0411	,8944	,0154	,0569	,0569	,0389	9,2500
10	.7380	.1347	.6033	.0000	.5154	20,5584	,9079	,0154	,0505	,0505	,0353	10,8700
11	.5068	.1337	.3731	.0000	.3691	19,6190	,9327	,0154	,0386	,0386	,0281	12,1200
12	.2440	.1329	.1111	.0000	.2030	16,9442	,9555	,0154	,0223	,0223	,0185	14,8700
13	.0292	.0292	.0000	.0000	.0292	13,8264	,9625	,0154	,0163	,0163	,0163	15,3700

TABLE A-13. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 A DIESEL+ETHANOL+30PCT WATER
TEST NO.05-01 FUEL: FM-465-F PROJECT:11-5830-006 DATE: 03/06/81

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 500.	0.	.0	.015	2.14	6.2	.942	217.	247.	1.53	490.	12.	28.	90.	1
2	2	INTER / 1400.	19.	2.8	.067	6.90	6.4	.951	350.	703.	2.20	535.	62.	246.	305.	2
3	25	INTER / 1400.	223.	32.7	.242	7.03	6.4	.950	870.	725.	5.07	538.	171.	271.	328.	3
4	50	INTER / 1400.	446.	65.4	.466	7.71	5.9	.940	585.	1877.	7.74	480.	126.	741.	309.	4
5	75	INTER / 1400.	670.	98.2	.735	8.82	6.8	.953	525.	3642.	9.66	525.	133.	1638.	385.	5
6	100	INTER / 1400.	893.	130.9	1.068	10.39	7.2	.957	288.	5503.	11.07	465.	90.	2990.	412.	6
7		IDLE / 500.	0.	.0	.015	2.15	6.8	.955	208.	256.	1.50	465.	12.	31.	91.	7
8	100	RATED / 2200.	814.	187.6	1.578	18.22	6.8	.953	295.	419.	9.25	365.	161.	406.	577.	8
9	75	RATED / 2200.	610.	140.6	1.150	15.77	7.2	.958	330.	219.	8.28	313.	150.	179.	418.	9
10	50	RATED / 2200.	408.	94.1	.823	13.89	7.2	.958	410.	457.	7.14	242.	159.	324.	280.	10
11	25	RATED / 2200.	204.	47.0	.490	12.21	6.9	.952	818.	1220.	5.36	220.	268.	752.	221.	11
12	2	RATED / 2200.	17.	3.8	.155	10.80	7.0	.952	610.	835.	3.00	290.	165.	442.	251.	12
13		IDLE / 500.	0.	.0	.015	2.14	7.0	.951	212.	268.	1.50	460.	13.	32.	91.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	13.98	31.63	*****	******	******	*****	.0069	.0687	.101	.984	.0075	8.7	.986	*****	.067	1
2	15.42	61.16	75.94	22.24	88.20	*****	.0098	.0689	.141	.978	.0110	12.8	.995	1.450	.080	2
3	11.77	18.66	22.59	5.23	8.28	10.03	.0347	.0844	.340	.942	.0303	5.5	.995	.446	.080	3
4	4.52	26.50	11.06	1.93	11.33	4.73	.0609	.0934	.503	.905	.0504	7.5	.998	.428	.080	4
5	3.02	37.12	8.73	1.36	16.68	3.92	.0839	.0987	.633	.877	.0666	6.5	1.002	.448	.080	5
6	1.41	46.67	6.43	.69	22.85	3.15	.1035	.1011	.752	.858	.0782	2.7	1.008	.486	.080	6
7	13.66	33.41	99.03	******	******	*****	.0071	.0687	.104	.985	.0074	3.3	.986	*****	.067	7
8	1.70	4.29	6.10	.86	2.16	3.08	.0872	.1034	.613	.879	.0645	1.8	1.051	.480	.080	8
9	2.17	2.60	6.05	1.07	1.27	2.97	.0735	.1011	.534	.892	.0568	5.2	1.033	.475	.080	9
10	3.21	6.56	5.67	1.69	3.45	2.98	.0597	.0981	.455	.908	.0481	7.8	1.022	.514	.080	10
11	9.11	25.61	7.54	5.69	15.99	4.71	.0404	.0914	.345	.933	.0349	10.6	1.014	.616	.080	11
12	17.79	47.62	26.98	43.12	115.45	65.42	.0144	.0726	.187	.969	.0158	16.0	1.009	2.403	.080	12
13	13.91	34.94	97.86	******	******	*****	.0073	.0687	.106	.985	.0074	1.6	.989	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC -------- = 1.889 GRAM/KW-HR (1.409 GRAM/BHP-HR)
BSCO -------- = 10.042 GRAM/KW-HR (7.491 GRAM/BHP-HR)
BSNOX ------- = 4.624 GRAM/KW-HR (3.449 GRAM/BHP-HR)
BSHC + BSNOX = 6.513 GRAM/KW-HR (4.859 GRAM/BHP-HR)
CORR. BSFC - = .498 KG/KW-HR (.819 LBS/BHP-HR)

TABLE A-13 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 A DIESEL+ETHANOL+30PCT WATER
TEST NO.05-01 FUEL: EM-465-F PROJECT:11-5830-006 DATE: 03/06/81

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	F/A RATIO FUEL CARBON	F/A RATIO EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0147	.0147	.0000	.0000	.0147	13,8764	,9843	,0099	,0069	,0069	,0069	0,0000
2	.0669	.0662	.0005	.0002	.0665	13,9185	,9779	,0103	,0098	,0097	,0097	0,0000
3	.2422	.1024	.0975	.0418	.1644	17,2059	,9422	,0199	,0347	,0287	,0235	0,0000
4	.4662	.1107	.2489	.1067	.2677	19,1461	,9053	,0319	,0609	,0469	,0349	0,0000
5	.7352	.1112	.4368	.1872	.3868	20,3147	,8771	,0452	,0839	,0625	,0441	0,0000
6	1.0629	.1254	.6598	.2828	.5416	20,8395	,8575	,0556	,1035	,0761	,0525	0,0000
7	.0152	.0152	.0000	.0000	.0152	13,8764	,9845	,0109	,0071	,0071	,0071	0,0000
8	1.5784	.1395	1,0072	.4317	.7750	21,3233	,8788	,0493	,0872	,0634	,0428	0,0000
9	1.1501	.1350	.7106	.3045	.5833	20,8399	,8924	,0428	,0735	,0540	,0373	0,0000
10	.8234	.1319	.4841	.2075	.4373	20,1831	,9082	,0357	,0597	,0447	,0317	0,0000
11	.4896	.1333	.2494	.1069	.2907	18,7289	,9334	,0253	,0404	,0316	,0240	0,0000
12	.1547	.1250	.0208	.0089	.1381	14,7118	,9684	,0125	,0144	,0136	,0129	0,0000
13	.0154	.0154	.0000	.0000	.0154	13,8764	,9845	,0112	,0073	,0073	,0073	0,0000

TABLE A-14. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: VOLVO TD-100 A   DIESEL+ETHANOL+30PCT WATER
TEST NO.05-02   FUEL: EM-465-F   PROJECT: 11-5830-006   DATE: 3/06/81

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 500.	0.	,0	,014	2,19	7,3	,975	225,	293,	1,58	470,	12,	31,	82,	1
2	2	INTER / 1400.	19.	2,8	,065	6,86	7,3	,974	389,	716,	2,28	502,	65,	238,	272,	2
3	25	INTER / 1400.	223.	32,7	,242	7,10	7,4	,966	855,	760,	5,19	525,	165,	278,	313,	3
4	50	INTER / 1400.	446.	65,4	,468	7,76	7,8	,968	565,	1847,	7,84	465,	121,	723,	297,	4
5	75	INTER / 1400.	670.	98,2	,736	8,85	7,8	,966	500,	3538,	9,66	478,	128,	1600,	353,	5
6	100	INTER / 1400.	893.	130,9	1,042	10,39	7,6	,962	300,	5504,	10,97	460,	91,	2872,	392,	6
7		IDLE / 500.	0.	,0	,015	2,15	7,6	,966	225,	256,	1,54	475,	13,	29,	88,	7
8	100	RATED / 2200.	814.	187,6	1,569	17,97	7,8	,966	285,	419,	9,43	350,	152,	396,	539,	8
9	75	RATED / 2200.	610.	140,6	1,111	15,77	8,3	,973	345,	219,	8,30	300,	151,	172,	385,	9
10	50	RATED / 2200.	408.	94,1	,823	14,23	8,3	,974	410,	470,	7,00	230,	162,	340,	271,	10
11	25	RATED / 2200.	204.	47,0	,490	12,13	8,3	,976	805,	1229,	5,34	205,	264,	761,	207,	11
12	2	RATED / 2000.	19.	4,0	,169	10,74	8,3	,979	680,	956,	3,03	237,	194,	533,	215,	12
13		IDLE / 500.	0.	,0	,013	2,19	8,3	,981	207,	244,	1,52	405,	11,	25,	68,	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	14,02	36,24	94,85	******	******	*****	,0066	,0687	,096	,983	,0078	17,7	,988	*****	,067	1
2	16,65	60,45	69,15	23.49	85,28	97,55	,0096	,0687	,140	,977	,0113	18,0	,993	1,420	,080	2
3	11,32	19,11	21,54	5,03	8,49	9,57	,0344	,0844	,337	,941	,0309	8,9	,995	,446	,080	3
4	4,32	25,74	10,57	1.85	11,05	4,54	,0608	,0934	,502	,904	,0510	8,9	,999	,430	,080	4
5	2,89	36,23	7,99	1.30	16,29	3,59	,0838	,0986	,635	,877	,0664	6,1	1,003	,449	,080	5
6	1,45	45,93	6,26	,69	21,94	2,99	,1010	,1027	,717	,856	,0787	6,9	1,009	,473	,080	6
7	14,40	32,54	98,50	******	******	*****	,0070	,0687	,102	,984	,0076	8,2	,988	*****	,067	7
8	1,62	4,20	5,73	,81	2,11	2,87	,0880	,1035	,618	,876	,0657	2,9	1,054	,476	,080	8
9	2,26	2,59	5,78	1.07	1,23	2,74	,0710	,1012	,516	,892	,0570	9,2	1,036	,457	,080	9
10	3,27	6,88	5,49	1,72	3,61	2,88	,0584	,0981	,445	,910	,0473	8,3	1,027	,511	,080	10
11	9,00	25,90	7,05	5.62	16,17	4,40	,0407	,0914	,348	,933	,0348	9,4	1,017	,614	,080	11
12	19,10	52,46	21,22	48,74	133,89	54,16	,0159	,0735	,201	,968	,0162	9,5	1,012	2,521	,080	12
13	13,44	31,47	85,22	******	******	*****	,0061	,0687	,089	,984	,0074	22,1	,989	*****	,067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS
BSHC ------- = 1,895 GRAM/KW-HR (1,413 GRAM/BHP-HR)
BSCO ------- = 9,936 GRAM/KW-HR (7,412 GRAM/BHP-HR)
BSNOX ------ = 4,286 GRAM/KW-HR (3,197 GRAM/BHP-HR)
BSHC + BSNOX = 6,180 GRAM/KW-HR (4,610 GRAM/BHP-HR)
CORR. BSFC - = ,492 KG/KW-HR (,809 LBS/BHP-HR)

TABLE A-14 (cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE:VOLVO TD-100 A   DIESEL+ETHANOL+30PCT WATER
TEST NO.05-02   FUEL: EM-465-F   PROJECT:11-5830-006   DATE: 3/06/81

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	ALCOHOL PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	F/A RATIO FUEL CARBON	F/A RATIO EQIV. DIESEL	EXHAUST OXYGEN PERCENT
1	.0143	.0143	.0000	.0000	.0143	13.8764	.9834	.0117	.0066	.0066	.0066	0.0000
2	.0655	.0655	.0000	.0000	.0655	13.8764	.9769	.0117	.0096	.0096	.0096	0.0000
3	.2422	.1029	.0975	.0418	.1644	17.2059	.9406	.0215	.0344	.0284	.0233	0.0000
4	.4684	.1107	.2504	.1073	.2686	19.1597	.9038	.0350	.0608	.0469	.0349	0.0000
5	.7360	.1134	.4358	.1868	.3883	20.2730	.8772	.0468	.0838	.0626	.0442	0.0000
6	1.0420	.1004	.6588	.2823	.5165	21.1794	.8564	.0562	.1010	.0737	.0501	0.0000
7	.0149	.0149	.0000	.0000	.0149	13.8764	.9839	.0122	.0070	.0070	.0070	0.0000
8	1.5692	.1368	1.0027	.4297	.7694	21.3443	.8764	.0514	.0880	.0639	.0431	0.0000
9	1.1106	.1295	.6867	.2943	.5628	20.8515	.8918	.0435	.0710	.0522	.0360	0.0000
10	.8234	.1319	.4841	.2075	.4373	20.1831	.9036	.0369	.0584	.0437	.0310	0.0000
11	.4896	.1333	.2494	.1069	.2907	18.7289	.9333	.0276	.0407	.0318	.0242	0.0000
12	.1693	.1308	.0269	.0115	.1478	14.8867	.9680	.0150	.0159	.0148	.0139	0.0000
13	.0132	.0132	.0000	.0000	.0132	13.8764	.9837	.0133	.0061	.0061	.0061	0.0000

APPENDIX B

TRANSIENT TEST RESULTS FROM THE DIESEL CONFIGURATION

TABLE B-1. NOTES CONCERNING TEST RESULTS GIVEN IN APPENDIX B

Test No.	Notes
Cold Start	
B-2	Passed statistical requirements. Results used for regulated emissions.
B-3	Passed statistical requirements. Results used for regulated emissions.
B-4	Passed statistical requirements. Results used for regulated emissions.
Hot Start	
B-5	Passed statistical requirements. Results used for regulated emissions.
B-6	Passed statistical requirements. Results used for regulated emissions.
B-7	Passed statistical requirements. Results used for regulated emissions.
Bus Cycle	
B-8	Failed statistical requirements, torque $r^2 = .869$. Results used for regulated emissions.
B-9	Passed statistical requirements. Results used for regulated emissions.

TABLE B-2.

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                                         ENGINE EMISSION RESULTS
                                                C-TRANS.                                   PROJECT NO. 11-4686-032

ENGINE  NO.D26                           TEST NO.D26-1  RUN1
ENGINE  MODEL   81 VOLVO DIESEL          DATE  3/24/81
ENGINE  0.0 L(  0. CID) I-6              TIME 1:35                          DIESEL   EM-465-F
CVS NO.  10                                DYNO NO.  5                      BAG CART NO.  1

BAROMETER 745.24 MM HG(29.34 IN HG)      RELATIVE HUMIDITY ,  ENGINE-50. PCT ,  CVS-72. PCT
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)    ABSOLUTE HUMIDITY  9.8 GM/KG( 68.4 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                   1                  2                  3                  4
  DESCRIPTION                                NYNF               LANF                LAF               NYNF
  BLOWER DIF P MM. H2O(IN. H2O)          751.8 (29.6)       751.8 (29.6)       751.8 (29.6)       751.8 (29.6)
  BLOWER INLET P MM. H2O(IN. H2O)        566.4 (22.3)       566.4 (22.3)       566.4 (22.3)       566.4 (22.3)
  BLOWER INLET TEMP. DEG. C(DEG. F)       50.0 (122.0)       50.0 (122.0)       50.0 (122.0)       50.0 (122.0)
  BLOWER REVOLUTIONS                        6179.              6262.              6368.              6179.
  TIME SECONDS                             296.0              300.0              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)        300.9 (10627.)     304.9 (10769.)     310.1 (10952.)     301.8 (10661.)

  HC   SAMPLE METER/RANGE/PPM            40.3/22/  40.      32.4/22/  32.      33.0/22/  33.      21.2/22/  21.
  HC   BCKGRD METER/RANGE/PPM             8.4/ 2/   8.       8.9/ 2/   9.       9.0/ 2/   9.       9.1/ 2/   9.
  CO   SAMPLE METER/RANGE/PPM            52.0/13/  49.      36.1/13/  33.      47.0/13/  44.      19.3/13/  18.
  CO   BCKGRD METER/RANGE/PPM              .4/13/   0.        .1/13/   0.        .2/13/   0.        .1/13/   0.
  CO2  SAMPLE METER/RANGE/PCT            20.0/ 3/  .32      24.6/ 3/  .40      54.2/ 3/  .95      16.5/ 3/  .26
  CO2  BCKGRD METER/RANGE/PCT             2.4/ 3/  .04       2.5/ 3/  .04       3.2/ 3/  .05       3.4/ 3/  .05
  NOX  SAMPLE METER/RANGE/PPM            11.4/13/  34.      14.2/13/  42.      34.7/13/ 104.      11.0/13/  33.
  NOX  BCKGRD METER/RANGE/PPM              .7/ 2/   1.        .9/ 3/   3.        .1/ 2/   0.        .7/ 2/   1.

  DILUTION FACTOR                           40.55              32.91              14.01              50.27
  HC   CONCENTRATION PPM                    32.                24.                25.                12.
  CO   CONCENTRATION PPM                    47.                32.                42.                17.
  CO2  CONCENTRATION PCT                    .29                .36                .90                .21
  NOX  CONCENTRATION PPM                    33.5               39.9              104.0               32.2

  HC   MASS GRAMS                           5.58               4.19               4.40               2.14
  CO   MASS GRAMS                          16.61              11.47              15.22               5.97
  CO2  MASS GRAMS                          1575.2             2030.3             5128.5             1170.2
  NOX  MASS GRAMS                          19.26              23.25              61.69              18.58
  FUEL KG (LB)                             .511 (   1.13)     .650 (   1.43)    1.629 (   3.59)     .374 (    .82)
  KW HR (HP HR)                            1.22 (   1.64)     1.95 (   2.61)     6.02 (   8.08)     1.11 (   1.49)

  BSHC G/KW HR (G/HP HR)                   4.56 (   3.40)     2.15 (   1.61)      .73 (    .54)     1.92 (   1.44)
  BSCO G/KW HR (G/HP HR)                  13.59 (  10.14)     5.90 (   4.40)     2.53 (   1.88)     5.38 (   4.01)
  BSCO2 G/KW HR (G/HP HR)               1288.97 ( 961.18)  1043.72 ( 778.30)   851.49 ( 634.95)  1054.39 ( 786.26)
  BSNOX G/KW HR (G/HP HR)                 15.76 (  11.75)    11.95 (   8.91)    10.24 (   7.64)    16.75 (  12.49)
  BSFC KG/KW HR (LB/HP HR)                 .418 (   .687)     .334 (   .550)     .271 (   .445)     .337 (   .554)

TOTAL TEST RESULTS 4 BAGS                              PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)           10.30 ( 13.81)           90MM FILTER
   BSHC    G/KW HR (G/HP HR)     1.58 (  1.18)              SAMPLE FLOW       SCM(SCF)                  .904 ( 31.93)
   BSCO    G/KW HR (G/HP HR)     4.78 (  3.57)              MULTIPLIER FOR  G/TEST                     1.347
   BSCO2   G/KW HR (G/HP HR)     962. (  717.)              MULTIPLIER FOR  G/KW HR (G/HP HR)           .1308 ( .0975)
   BSNOX   G/KW HR (G/HP HR)    11.92 (  8.89)              MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)       .4256 ( .1931)
   BSFC  KG/KW HR (LB/HP HR)     .307 (  .505)
                                                         20 X 20 FILTERS
   PART. G/KW-HR (G/HP-HR) 0.79 (0.59)                      SAMPLE FLOW     SCM(SCF)                   82.98 (2930.8)
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TABLE B-3. ENGINE EMISSION RESULTS

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                                            C-TRANS.                          PROJECT NO. 11-5044-001

ENGINE  NO.D26                        TEST NO.D26-2  RUN1
ENGINE  MODEL    81 VOLVO DIESEL      DATE  3/25/81
ENGINE  0.0 L(   0. CID) I-6          TIME 1:05                   DIESEL   EM-465-F
CVS NO.  10                             DYNO NO.  5                 BAG CART NO.  1

BAROMETER 743.46 MM HG(29.27 IN HG)   RELATIVE HUMIDITY ,  ENGINE-52. PCT ,  CVS-42. PCT
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F) ABSOLUTE HUMIDITY 10.6 GM/KG( 73.9 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                 1                 2                 3                 4
  DESCRIPTION                               NYNF              LANF              LAF               NYNF
  BLOWER DIF P MM. H2O(IN. H2O)       754.4 (29.7)      754.4 (29.7)      754.4 (29.7)      754.4 (29.7)
  BLOWER INLET P MM. H2O(IN. H2O)     584.2 (23.0)      584.2 (23.0)      584.2 (23.0)      584.2 (23.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)    49.4 (121.0)      49.4 (121.0)      49.4 (121.0)      49.4 (121.0)
  BLOWER REVOLUTIONS                      6180.             6263.             6369.             6200.
  TIME SECONDS                            296.0             300.0             305.0             297.0
  TOTAL FLOW STD. CU. METRES(SCF)     300.0 (10597.)    304.1 (10739.)    309.2 (10921.)    301.0 (10631.)

   HC  SAMPLE METER/RANGE/PPM         44.7/22/  45.     32.4/22/  32.     32.9/22/  33.     22.0/22/  22.
   HC  BCKGRD METER/RANGE/PPM          9.0/ 2/   9.      9.0/ 2/   9.      8.6/ 2/   9.      8.8/ 2/   9.
   CO  SAMPLE METER/RANGE/PPM         56.6/13/  54.     37.3/13/  35.     47.8/13/  45.     19.2/13/  17.
   CO  BCKGRD METER/RANGE/PPM           .2/13/   0.       .3/13/   0.       .2/13/   0.       .3/13/   0.
   CO2 SAMPLE METER/RANGE/PCT         19.7/ 3/  .32     25.0/ 3/  .41     54.2/ 3/  .95     15.7/ 3/  .25
   CO2 BCKGRD METER/RANGE/PCT          2.9/ 3/  .04      2.8/ 3/  .04      2.7/ 3/  .04      2.8/ 3/  .04
   NOX SAMPLE METER/RANGE/PPM         10.8/13/  32.     14.0/13/  42.     34.1/13/ 102.     10.6/13/  32.
   NOX BCKGRD METER/RANGE/PPM          1.3/ 2/   1.      1.1/ 2/   1.      1.1/ 2/   1.       .9/ 2/   1.

   DILUTION FACTOR                      41.07             32.35             14.01             52.09
   HC  CONCENTRATION PPM                 36.               24.               25.               13.
   CO  CONCENTRATION PPM                 53.               34.               43.               17.
   CO2 CONCENTRATION PCT                 .27               .37               .91               .21
   NOX CONCENTRATION PPM                31.0              40.8             101.2              30.8

   HC  MASS GRAMS                       6.21              4.14              4.44              2.31
   CO  MASS GRAMS                      18.41             11.87             15.61              5.92
   CO2 MASS GRAMS                     1501.5            2038.6            5154.8            1143.4
   NOX MASS GRAMS                      17.78             23.75             59.88             17.75
   FUEL KG (LB)                        .489 (    1.08)   .653 (    1.44)  1.638 (    3.61)   .366 (     .81)
   KW HR (HP HR)                       1.15 (    1.54)   1.97 (    2.64)   6.01 (    8.06)   1.15 (    1.54)

   BSHC G/KW HR (G/HP HR)              5.41 (    4.04)   2.10 (    1.57)    .74 (     .55)   2.02 (    1.50)
   BSCO G/KW HR (G/HP HR)             16.05 (   11.97)   6.04 (    4.50)   2.60 (    1.94)   5.16 (    3.85)
   BSCO2 G/KW HR (G/HP HR)          1308.78 (  975.96) 1034.69 (  771.57) 857.63 (  639.53) 996.68 (  743.22)
   BSNOX G/KW HR (G/HP HR)            15.50 (   11.56)  12.06 (    8.99)   9.96 (    7.43)  15.47 (   11.54)
   BSFC KG/KW HR (LB/HP HR)            .426 (    .701)   .331 (    .545)   .273 (    .448)   .319 (    .524)

TOTAL TEST RESULTS 4 BAGS                         PARTICULATE DATA, TOTAL FOR 4 BAGS

   TOTAL KW HR (HP HR)          10.28 ( 13.78)          90MM FILTER
    BSHC    G/KW HR (G/HP HR)    1.67 (  1.24)               SAMPLE FLOW      SCM(SCF)                 .911 ( 32.19)
    BSCO    G/KW HR (G/HP HR)    5.04 (  3.76)               MULTIPLIER FOR   G/TEST                  1.332
    BSCO2   G/KW HR (G/HP HR)    957. (  714.)               MULTIPLIER FOR   G/KW HR (G/HP HR)        .1297 ( .0967)
    BSNOX   G/KW HR (G/HP HR)   11.60 (  8.65)               MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)    .4235 ( .1921)
    BSFC   KG/KW HR (LB/HP HR)   .306 (  .503)
                                                          20 X 20 FILTERS
   PART. G/KW-HR (G/HP-HR) 0.78 (0.58)                        SAMPLE FLOW     SCM(SCF)                83.25 (2940.4)
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                              TABLE B-4.   ENGINE EMISSION RESULTS                                      PROJECT NO. 11-5044-001
                                                C-TRANS.

ENGINE  NO.D26                                TEST NO.D26-3  RUN1
ENGINE  MODEL    81 VOLVO DIESEL              DATE  3/26/81
ENGINE  0.0 L(  0. CID) I-6                   TIME 9:37                          DIESEL   EM-465-F
CVS NO.  10                                    DYNO NO.  5                        BAG CART NO.  1

BAROMETER 745.24 MM HG(29.34 IN HG)           RELATIVE HUMIDITY ,  ENGINE-62. PCT ,  CVS-52. PCT
DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)         ABSOLUTE HUMIDITY 11.3 GM/KG( 78.9 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                        1                  2                  3                  4
  DESCRIPTION                                      NYNF               LANF               LAF                NYNF
  BLOWER DIF P MM. H2O(IN. H2O)              756.9 (29.8)       756.9 (29.8)       756.9 (29.8)       756.9 (29.8)
  BLOWER INLET P MM. H2O(IN. H2O)            576.6 (22.7)       576.6 (22.7)       576.6 (22.7)       576.6 (22.7)
  BLOWER INLET TEMP. DEG. C(DEG. F)           49.4 (121.0)       49.4 (121.0)       49.4 (121.0)       49.4 (121.0)
  BLOWER REVOLUTIONS                           6179.              6263.              6367.              6200.
  TIME SECONDS                                 296.0              300.0              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)            300.4 (  10611.)   304.5 (10755.)     309.6 (10934.)     301.4 (10647.)

  HC  SAMPLE METER/RANGE/PPM                34.7/22/  35.      31.9/22/  32.      32.3/22/  32.      22.2/22/  22.
  HC  BCKGRD METER/RANGE/PPM                 8.2/ 2/   8.       9.0/ 2/   9.       9.0/ 2/   9.       8.9/ 2/   9.
  CO  SAMPLE METER/RANGE/PPM                46.9/13/  44.      36.6/13/  34.      47.6/13/  45.      19.6/13/  18.
  CO  BCKGRD METER/RANGE/PPM                  .5/13/   0.        .2/13/   0.        .1/13/   0.        .3/13/   0.
  CO2 SAMPLE METER/RANGE/PCT                19.5/ 3/  .31      25.1/ 3/  .41      53.8/ 3/  .94      16.3/ 3/  .26
  CO2 BCKGRD METER/RANGE/PCT                 3.0/ 3/  .05       3.0/ 3/  .05       3.1/ 3/  .05       3.1/ 3/  .05
  NOX SAMPLE METER/RANGE/PPM                11.3/13/  34.      13.9/13/  42.      33.9/13/ 102.      11.2/13/  33.
  NOX BCKGRD METER/RANGE/PPM                  .7/ 2/   1.        .7/ 2/   1.        .9/ 2/   1.        .7/ 2/   1.

  DILUTION FACTOR                              41.75              32.22              14.13              50.88
  HC  CONCENTRATION PPM                        27.                23.                24.                13.
  CO  CONCENTRATION PPM                        43.                33.                43.                17.
  CO2 CONCENTRATION PCT                        .27                .36                .90                .21
  NOX CONCENTRATION PPM                        33.3               40.9              100.7               32.8

  HC  MASS GRAMS                               4.63               4.07               4.28               2.34
  CO  MASS GRAMS                              14.91              11.67              15.54               6.03
  CO2 MASS GRAMS                            1476.4             2034.6             5083.8             1175.3
  NOX MASS GRAMS                              19.15              23.05              59.64              18.90
  FUEL KG (LB)                               .478 (   1.05)    .652 (   1.44)   1.615 (   3.56)    .376 (    .83)
  KW HR (HP HR)                              1.16 (   1.56)    1.75 (   2.61)    6.04 (   8.09)    1.13 (   1.52)

  BSHC G/KW HR (G/HP HR)                     3.99 (   2.98)    2.09 (   1.56)     .71 (    .53)    2.07 (   1.54)
  BSCO G/KW HR (G/HP HR)                    12.85 (   9.59)    6.00 (   4.47)    2.57 (   1.92)    5.32 (   3.96)
  BSCO2 G/KW HR (G/HP HR)                 1273.08 ( 949.34) 1045.92 ( 779.94)  842.32 ( 628.12) 1035.71 ( 772.33)
  BSNOX G/KW HR (G/HP HR)                   16.51 (  12.31)   12.26 (   9.14)    9.88 (   7.37)   16.65 (  12.42)
  BSFC KG/KW HR (LB/HP HR)                   .412 (   .677)    .335 (   .551)    .268 (   .440)    .331 (   .545)

TOTAL TEST RESULTS 4 BAGS                             PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)           10.28 ( 13.78)           90MM FILTER
   BSHC    G/KW HR (G/HP HR)     1.49 (  1.11)               SAMPLE FLOW      SCM(SCF)                   .885 ( 31.27)
   BSCO    G/KW HR (G/HP HR)     4.69 (  3.49)               MULTIPLIER FOR   G/TEST                    1.373
   BSCO2   G/KW HR (G/HP HR)     951. (  709.)               MULTIPLIER FOR   G/KW HR (G/HP HR)          .1337 ( .0997)
   BSNOX   G/KW HR (G/HP HR)    11.83 (  8.82)               MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)      .4401 ( .1996)
   BSFC   KG/KW HR (LB/HP HR)    .304 (  .499)
   PART. G/KW-HR (G/HP-HR) 0.85 (0.63)                   20 X 20 FILTERS
                                                             SAMPLE FLOW      SCM(SCF)                 81.28 (2870.8)
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TABLE B-5.

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                                                ENGINE EMISSION RESULTS
                                                        H-TRANS.                                           PROJECT NO. 11 4606 032

ENGINE  NO.D26                                  TEST NO.D26-1  RUN1
ENGINE  MODEL   81 VOLVO DIESEL                 DATE  3/24/81
ENGINE  0.0 L(  0. CID) I-6                     TIME 2.22                                 DIESEL   EM-465-F
CVS NO.  10                                       DYNO NO.  5                               BAG CART NO.  1

BAROMETER 744.22 MM HG(29.30 IN HG)             RELATIVE HUMIDITY ,  ENGINE-55. PCT ,  CVS-72. PCT
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)           ABSOLUTE HUMIDITY 11.4 GM/KG( 80.0 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
    BAG NUMBER                                        1                    2                    3                    4
    DESCRIPTION                                      NYNF                 LANF                 LAF                  NYNF
    BLOWER DIF P MM. H2O(IN. H2O)               726.4 (28.6)         726.4 (28.6)         726.4 (28.6)         726.4 (28.6)
    BLOWER INLET P MM. H2O(IN. H2O)             566.4 (22.3)         566.4 (22.3)         566.4 (22.3)         566.4 (22.3)
    BLOWER INLET TEMP. DEG. C(DEG. F)            50.0 (122.0)         50.0 (122.0)         50.0 (122.0)         50.0 (122.0)
    BLOWER REVOLUTIONS                              6179.                6262.                6368.                6201.
    TIME SECONDS                                   296.0                300.0                305.0                297.0
    TOTAL FLOW STD. CU. METRES(SCF)             300.8 (10623.)       304.8 (10766.)       310.0 (10948.)       301.8 (10661.)

    HC  SAMPLE METER/RANGE/PPM                  21.8/22/  22.        24.8/22/  25.        28.9/22/  29.        21.1/22/  21.
    HC  BCKGRD METER/RANGE/PPM                   9.1/ 2/   9.         8.9/ 2/   9.         8.3/ 2/   8.         8.2/ 2/   8.
    CO  SAMPLE METER/RANGE/PPM                  22.8/13/  21.        30.3/13/  28.        56.8/13/  54.        21.2/13/  19.
    CO  BCKGRD METER/RANGE/PPM                    .6/13/   1.          .8/13/   1.        1.0/13/   1.         1.0/13/   1.
    CO2 SAMPLE METER/RANGE/PCT                  17.2/ 3/  .27        23.9/ 3/  .39        54.6/ 3/  .96        15.9/ 3/  .25
    CO2 BCKGRD METER/RANGE/PCT                   2.8/ 3/  .04         2.7/ 3/  .04         2.8/ 3/  .04         2.6/ 3/  .04
    NOX SAMPLE METER/RANGE/PPM                  10.8/13/  32.        13.3/13/  40.        34.0/13/ 102.        10.4/13/  31.
    NOX BCKGRD METER/RANGE/PPM                    .8/ 2/   1.          .9/ 2/   1.         1.0/ 2/   1.          .8/ 2/   1.

    DILUTION FACTOR                               40.09                34.04                13.87                52.19
    HC  CONCENTRATION PPM                          13.                  16.                  21.                  13.
    CO  CONCENTRATION PPM                          20.                  26.                  51.                  18.
    CO2 CONCENTRATION PCT                          .23                  .35                  .92                  .21
    NOX CONCENTRATION PPM                          31.6                 39.2                101.1                 30.3

    HC  MASS GRAMS                                 2.24                 2.84                 3.79                 2.27
    CO  MASS GRAMS                                 6.90                 9.34                18.43                 6.29
    CO2 MASS GRAMS                               1280.7               1745.0               5203.8               1181.7
    NOX MASS GRAMS                                18.19                22.83                59.92                17.52
    FUEL KG (LB)                                   .410 (    .90)      .621 (   1.37)     1.654 (   3.65)       .378 (    .83)
    KW HR (HP HR)                                  1.52 (   2.04)      2.06 (   2.76)      6.27 (   8.41)       1.13 (   1.52)

    BSHC G/KW HR (G/HP HR)                         1.47 (   1.10)      1.38 (   1.03)       .60 (    .45)       2.00 (   1.49)
    BSCO G/KW HR (G/HP HR)                         4.53 (   3.38)      4.54 (   3.39)      2.94 (   2.19)       5.55 (   4.14)
    BSCO2 G/KW HR (G/HP HR)                      841.81 ( 627.74)    945.30 ( 704.91)    829.64 ( 618.67)    1041.38 ( 776.56)
    BSNOX G/KW HR (G/HP HR)                       11.96 (   8.92)     11.10 (   8.27)      9.55 (   7.12)      15.44 (  11.51)
    BSFC KG/KW HR (LB/HP HR)                       .269 (   .443)      .302 (   .496)      .264 (   .434)       .333 (   .548)

TOTAL TEST RESULTS 4 BAGS                                   PARTICULATE DATA, TOTAL FOR 4 BAGS

   TOTAL KW HR (HP HR)            10.99 ( 14.73)                 90MM FILTER
    BSHC    G/KW HR (G/HP HR)      1.01 (   .76)                     SAMPLE FLOW      SCM(SCF)                    .944 ( 33.34)
    BSCO    G/KW HR (G/HP HR)      3.73 (  2.78)                     MULTIPLIER FOR   G/TEST                     1.290
    BSCO2   G/KW HR (G/HP HR)      875. (  652.)                     MULTIPLIER FOR   G/KW HR (G/HP HR)           .1174 ( .0875)
    BSNOX   G/KW HR (G/HP HR)     10.78 (  8.04)                     MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)       .4211 ( .1910)
    BSFC  KG/KW HR (LB/HP HR)      .279 (  .458)
                                                                 20 X 20 FILTERS
    PART. G/KW-HR (G/HP-HR) 0.67 (0.50)                               SAMPLE FLOW     SCM(SCF)                    83.07 (2934.0)
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TABLE B-6. ENGINE EMISSION RESULTS
H-TRANS.

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                                                                                   PROJECT NO. 11-5044-001

ENGINE  NO.D26                            TEST NO.D26-2  RUN1
ENGINE  MODEL   81 VOLVO DIESEL           DATE  3/25/81
ENGINE  0.0 L(  0. CID) I-6               TIME 1:52                  DIESEL   EM-465-F
CVS NO.  10                                DYNO NO.  5                BAG CART NO.  1

BAROMETER 742.95 MM HG(29.25 IN HG)       RELATIVE HUMIDITY ,  ENGINE-52. PCT ,  CVS-42. PCT
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)     ABSOLUTE HUMIDITY 10.6 GM/KG( 73.9 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                    1                  2                  3                  4
  DESCRIPTION                                 NYNF               LANF               LAF                NYNF
  BLOWER DIF P MM. H2O(IN. H2O)          754.4 (29.7)       754.4 (29.7)       754.4 (29.7)       754.4 (29.7)
  BLOWER INLET P MM. H2O(IN. H2O)        584.2 (23.0)       584.2 (23.0)       584.2 (23.0)       584.2 (23.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)       49.4 (121.0)       49.4 (121.0)       49.4 (121.0)       49.4 (121.0)
  BLOWER REVOLUTIONS                        6179.              6263.              6369.              6200.
  TIME SECONDS                              296.0              300.0              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)        299.8 (10589.)     303.7 (10733.)     309.0 (10914.)     300.8 (10625.)

  HC   SAMPLE METER/RANGE/PPM            23.3/22/  23.      25.0/22/  25.      31.0/22/  31.      21.5/22/  21.
  HC   BCKGRD METER/RANGE/PPM             9.2/ 2/   9.       9.0/ 2/   9.       8.9/ 2/   9.       8.7/ 2/   9.
  CO   SAMPLE METER/RANGE/PPM            21.9/13/  20.      30.0/13/  28.      56.2/13/  54.      21.9/13/  20.
  CO   BCKGRD METER/RANGE/PPM              .1/13/   0.        .4/13/   0.        .3/13/   0.        .6/13/   1.
  CO2  SAMPLE METER/RANGE/PCT            15.7/ 3/  .25      23.7/ 3/  .39      53.4/ 3/  .93      15.7/ 3/  .25
  CO2  BCKGRD METER/RANGE/PCT             2.6/ 3/  .04       2.3/ 3/  .04       2.4/ 3/  .04       2.2/ 3/  .03
  NOX  SAMPLE METER/RANGE/PPM            10.1/13/  30.      13.6/13/  41.      33.7/13/ 101.      11.0/13/  33.
  NOX  BCKGRD METER/RANGE/PPM             1.1/ 2/   1.       1.0/ 2/   1.       1.4/ 2/   1.       1.1/ 2/   1.

  DILUTION FACTOR                           52.81              34.34              14.24              52.85
  HC   CONCENTRATION PPM                    14.                16.                23.                13.
  CO   CONCENTRATION PPM                    20.                27.                52.                19.
  CO2  CONCENTRATION PCT                     .21                .35                .90                .22
  NOX  CONCENTRATION PPM                    29.3               39.9               99.7               31.8

  HC   MASS GRAMS                            2.46               2.84               4.05               2.25
  CO   MASS GRAMS                            6.81               9.43              18.56               6.60
  CO2  MASS GRAMS                         1155.4             1953.0             5087.2             1192.6
  NOX  MASS GRAMS                           16.79              23.21              58.93              18.30
  FUEL KG (LB)                             .370 (    .82)    .623 (   1.37)   1.618 (   3.57)    .382 (    .84)
  KW HR (HP HR)                            1.20 (   1.61)    2.02 (   2.71)    6.12 (   8.21)    1.18 (   1.59)

  BSHC  G/KW HR (G/HP HR)                  2.06 (   1.53)    1.41 (   1.05)     .66 (    .49)    1.90 (   1.41)
  BSCO  G/KW HR (G/HP HR)                  5.69 (   4.24)    4.67 (   3.48)    3.03 (   2.26)    5.64 (   4.21)
  BSCO2 G/KW HR (G/HP HR)                965.19 ( 719.74)  966.76 ( 720.91)  830.88 ( 619.59) 1006.74 ( 750.73)
  BSNOX G/KW HR (G/HP HR)                 14.03 (  10.46)   11.49 (   8.57)    9.62 (   7.18)   15.44 (  11.52)
  BSFC  KG/KW HR (LB/HP HR)                .309 (   .508)    .309 (   .507)    .264 (   .434)    .322 (   .530)

TOTAL TEST RESULTS 4 BAGS                        PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          10.52 ( 14.11)        90MM FILTER
   BSHC    G/KW HR (G/HP HR)    1.10 (   .82)          SAMPLE FLOW      SCM(SCF)                  .948 ( 33.49)
   BSCO    G/KW HR (G/HP HR)    3.94 (  2.94)          MULTIPLIER FOR   G/TEST                   1.200
   BSCO2   G/KW HR (G/HP HR)    892. (  665.)          MULTIPLIER FOR   G/KW HR (G/HP HR)         .1216 ( .0907)
   BSNOX   G/KW HR (G/HP HR)   11.14 (  8.31)          MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)     .4276 ( .1939)
   BSFC   KG/KW HR (LB/HP HR)   .204 (  .468)
                                                     20 X 20 FILTERS
   PART. G/KW-HR (G/HP-HR) 0.68 (0.51)                 SAMPLE FLOW      SCM(SCF)                 83.30 (2942.0)
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TABLE B-7. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 11-5044-001

ENGINE NO.D26
ENGINE MODEL 81 VOLVO DIESEL
ENGINE 0.0 L(0. CID) I-6
CVS NO. 10

TEST NO.D26-3 RUN1
DATE 3/26/81
TIME 10:20
DYNO NO. 5

DIESEL EM-465-F
BAG CART NO. 1

BAROMETER 745.24 MM HG(29.34 IN HG)
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)

RELATIVE HUMIDITY , ENGINE-53. PCT , CVS-52. PCT
ABSOLUTE HUMIDITY 10.7 GM/KG(75.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
BLOWER DIF P MM. H2O(IN. H2O)	756.9 (29.8)	756.9 (29.8)	756.9 (29.8)	756.9 (29.8)
BLOWER INLET P MM. H2O(IN. H2O)	576.6 (22.7)	576.6 (22.7)	576.6 (22.7)	576.6 (22.7)
BLOWER INLET TEMP. DEG. C(DEG. F)	49.4 (121.0)	49.4 (121.0)	49.4 (121.0)	49.4 (121.0)
BLOWER REVOLUTIONS	6179.	6263.	6360.	6199.
TIME SECONDS	296.0	300.0	305.0	297.0
TOTAL FLOW STD. CU. METRES(SCF)	300.4 (10608.)	304.4 (10753.)	309.5 (10933.)	301.3 (10643.)
HC SAMPLE METER/RANGE/PPM	21.8/22/ 22.	24.5/22/ 25.	28.8/22/ 29.	20.6/22/ 21.
HC BCKGRD METER/RANGE/PPM	9.0/ 2/ 9.	8.3/ 2/ 8.	7.9/ 2/ 8.	7.8/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	22.3/13/ 20.	30.2/13/ 28.	54.4/13/ 52.	19.9/13/ 18.
CO BCKGRD METER/RANGE/PPM	.1/13/ 0.	.1/13/ 0.	.1/13/ 0.	.1/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	15.9/ 3/ .25	23.6/ 3/ .38	53.5/ 3/ .93	15.8/ 3/ .25
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .05	2.9/ 3/ .04	3.1/ 3/ .05	3.3/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	9.7/13/ 29.	13.1/13/ 39.	32.7/13/ 98.	10.6/13/ 32.
NOX BCKGRD METER/RANGE/PPM	.0/12/ 0.	.7/ 2/ 1.	.8/ 2/ 1.	.7/ 2/ 1.
DILUTION FACTOR	52.15	34.49	14.21	52.56
HC CONCENTRATION PPM	13.	16.	21.	13.
CO CONCENTRATION PPM	20.	27.	50.	18.
CO2 CONCENTRATION PCT	.21	.34	.89	.20
NOX CONCENTRATION PPM	29.2	38.6	97.3	31.0
HC MASS GRAMS	2.25	2.89	3.83	2.25
CO MASS GRAMS	6.93	9.57	17.94	6.19
CO2 MASS GRAMS	1134.3	1896.9	5050.1	1112.0
NOX MASS GRAMS	16.75	22.50	57.60	17.88
FUEL KG (LB)	.363 (.80)	.606 (1.34)	1.605 (3.54)	.356 (.78)
KW HR (HP HR)	1.06 (1.42)	1.93 (2.59)	6.05 (8.11)	1.06 (1.42)
BSHC G/KW HR (G/HP HR)	2.13 (1.59)	1.50 (1.12)	.63 (.47)	2.12 (1.58)
BSCO G/KW HR (G/HP HR)	6.54 (4.87)	4.95 (3.69)	2.97 (2.21)	5.84 (4.35)
BSCO2 G/KW HR (G/HP HR)	1070.14 (798.01)	981.40 (731.83)	835.01 (622.67)	1049.13 (782.34)
BSNOX G/KW HR (G/HP HR)	15.81 (11.79)	11.64 (8.68)	9.52 (7.10)	16.87 (12.58)
BSFC KG/KW HR (LB/HP HR)	.343 (.564)	.313 (.515)	.265 (.436)	.336 (.552)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	10.10 (13.55)
BSHC G/KW HR (G/HP HR)	1.11 (.83)
BSCO G/KW HR (G/HP HR)	4.02 (3.00)
BSCO2 G/KW HR (G/HP HR)	910. (679.)
BSNOX G/KW HR (G/HP HR)	11.36 (8.47)
BSFC KG/KW HR (LB/HP HR)	.290 (.477)

PART. G/KW-HR (G/HP-HR) 0.70 (0.52)

PARTICULATE DATA, TOTAL FOR 4 BAGS

90MM FILTER

SAMPLE FLOW	SCM(SCF)	.873 (30.82)
MULTIPLIER FOR	G/TEST	1.393
MULTIPLIER FOR	G/KW HR (G/HP HR)	.1379 (.1029)
MULTIPLIER FOR	G/KG FUEL (G/LB FUEL)	.4754 (.2156)

20 X 20 FILTERS

SAMPLE FLOW	SCM(SCF)	81.00 (2861.0)

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                                   TABLE B-8.   ENGINE EMISSION RESULTS
                                                   H-TRANS.
ENGINE  NO.D26                                                                          PROJECT NO. 11-5044-001
ENGINE  MODEL    81 VOLVO DIESEL                  TEST NO.D26-1  RUN1
ENGINE  0.0 L(   0. CID) I-6                      DATE  3/25/81
CVS NO.  10                                       TIME 2:30
                                                    DYNO NO.  5                   DIESEL   EM-465-F
BAROMETER 742.44 MM HG(29.23 IN HG)                                                 BAG CART NO.  1
DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)             RELATIVE HUMIDITY ,  ENGINE-59. PCT ,  CVS-42. PCT
                                                  ABSOLUTE HUMIDITY 10.5 GM/KG( 73.4 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000
BAG RESULTS
  BAG NUMBER                                           1                  2                  3
  BLOWER DIF P MM. H2O(IN. H2O)                   754.4 (29.7)       754.4 (29.7)       754.4 (29.7)
  BLOWER INLET P MM. H2O(IN. H2O)                 504.2 (23.0)       504.2 (23.0)       504.2 (23.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)                49.4 (121.0)       49.4 (121.0)       49.4 (121.0)
  BLOWER REVOLUTIONS                                5697.              6010.              5693.
  TIME SECONDS                                      272.9              287.9              272.7
  TOTAL FLOW STD. CU. METRES(SCF)                 275.8 (   9742.)  291.0 (10277.)    275.6 ( 9735.)

  HC   SAMPLE METER/RANGE/PPM                     22.1/22/  22.      19.9/22/  20.      21.3/22/  21.
  HC   BCKGRD METER/RANGE/PPM                      8.3/ 2/   8.       9.0/ 2/   9.       8.8/ 2/   9.
  CO   SAMPLE METER/RANGE/PPM                     26.4/13/  24.      24.3/13/  22.      25.3/13/  23.
  CO   BCKGRD METER/RANGE/PPM                       .4/13/   0.        .3/13/   0.        .3/13/   0.
  CO2  SAMPLE METER/RANGE/PCT                     18.3/ 3/  .29      22.4/ 3/  .36      19.2/ 3/  .31
  CO2  BCKGRD METER/RANGE/PCT                      2.8/ 3/  .04       2.7/ 3/  .04       2.8/ 3/  .04
  NOX  SAMPLE METER/RANGE/PPM                      9.5/13/  28.      15.3/13/  46.      10.6/13/  32.
  NOX  BCKGRD METER/RANGE/PPM                       .9/ 2/   1.        .9/ 2/   1.        .9/ 2/   1.

  DILUTION FACTOR                                  45.05              36.53              42.88
  HC  CONCENTRATION PPM                            14.                11.                13.
  CO  CONCENTRATION PPM                            23.                21.                22.
  CO2 CONCENTRATION PCT                             .25                .32                .27
  NOX CONCENTRATION PPM                            27.6               45.0               30.8

  HC  MASS GRAMS                                   2.23               1.86               2.03
  CO  MASS GRAMS                                   7.50               7.28               7.20
  CO2 MASS GRAMS                                 1268.0             1718.4             1344.0
  NOX MASS GRAMS                                  14.57              25.07              16.24
  FUEL KG (LB)                                     .406 (    .89)     .547 (   1.21)     .429 (    .95)
  KW HR (HP HR)                                    1.22 (   1.64)     1.97 (   2.64)     1.43 (   1.92)

  BSHC G/KW HR (G/HP HR)                           1.82 (   1.36)      .95 (    .71)     1.41 (   1.05)
  BSCO G/KW HR (G/HP HR)                           6.14 (   4.58)     3.70 (   2.76)     5.02 (   3.74)
  BSCO2 G/KW HR (G/HP HR)                       1037.59 ( 773.73)   872.18 ( 650.39)   937.20 ( 698.87)
  BSNOX G/KW HR (G/HP HR)                         11.92 (   8.89)    12.72 (   9.49)    11.33 (   8.45)
  BSFC KG/KW HR (LB/HP HR)                         .332 (   .546)     .278 (   .457)     .299 (   .492)

TOTAL TEST RESULTS 3 BAGS                          PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)             4.63 (   6.20)      90MM FILTER
   BSHC   G/KW HR (G/HP HR)       1.32 (    .99)        SAMPLE FLOW        SCM(SCF)                      .652 ( 23.02)
   BSCO   G/KW HR (G/HP HR)       4.75 (   3.54)        MULTIPLIER FOR  G/TEST                          1.293
   BSCO2  G/KW HR (G/HP HR)       936. (   698.)        MULTIPLIER FOR  G/KW HR (G/HP HR)               .2774 ( .2081)
   BSNOX  G/KW HR (G/HP HR)      12.08 (   9.01)        MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)           .9348 ( .4240)
   BSFC  KG/KW HR (LB/HP HR)      .299 (   .491)
  PART. G/KW-HR (G/HP-HR) 0.83 (0.62)                 20 X 20 FILTERS
                                                        SAMPLE FLOW      SCM(SCF)                        56.75 (2004.4)
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TABLE B-9. ENGINE EMISSION RESULTS

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                                                        H-TRANS.
                                                                                        PROJECT NO. 11-5044-001
ENGINE  NO.D26                                   TEST NO.D26-2  RUN2
ENGINE  MODEL   81 VOLVO DIESEL                  DATE  3/25/81
ENGINE  0.0 L(  0. CID) I-6                      TIME 3:20                               DIESEL   CM-465-F
CVS NO.  10                                        DYNO NO.  5                             BAG CART NO.  1

BAROMETER 741.68 MM HG(29.20 IN HG)              RELATIVE HUMIDITY ,  ENGINE-51. PCT ,  CVS-43. PCT
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)            ABSOLUTE HUMIDITY 10.4 GM/KG( 72.6 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                           1                     2                     3
  BLOWER DIF P MM. H2O(IN. H2O)                 754.4 (29.7)          754.4 (29.7)          754.4 (29.7)
  BLOWER INLET P MM. H2O(IN. H2O)               584.2 (23.0)          584.2 (23.0)          584.2 (23.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)              49.4 (121.0)          49.4 (121.0)          49.4 (121.0)
  BLOWER REVOLUTIONS                               5694.                 6011.                 5697.
  TIME SECONDS                                    272.0                 288.0                 272.8
  TOTAL FLOW STD. CU. METRES(SCF)               275.4 (   9726.)     290.7 (10268.)        275.5 ( 9731.)

  HC   SAMPLE METER/RANGE/PPM                   22.3/22/  22.         19.1/22/  19.         21.2/22/  21.
  HC   BCKGRD METER/RANGE/PPM                    8.3/ 2/   8.          8.2/ 2/   8.          7.9/ 2/   8.
  CO   SAMPLE METER/RANGE/PPM                   24.1/13/  22.         22.8/13/  21.         23.8/13/  22.
  CO   BCKGRD METER/RANGE/PPM                     .1/13/   0.           .2/13/   0.           .1/13/   0.
  CO2  SAMPLE METER/RANGE/PCT                   17.9/ 3/  .29         22.7/ 3/  .37         19.6/ 3/  .31
  CO2  BCKGRD METER/RANGE/PCT                    3.6/ 3/  .06          3.1/ 3/  .05          3.4/ 3/  .05
  NOX  SAMPLE METER/RANGE/PPM                   10.4/13/  31.         16.3/13/  49.         10.9/13/  33.
  NOX  BCKGRD METER/RANGE/PPM                     .9/ 2/   1.          1.0/ 2/   1.           .9/ 2/   1.

  DILUTION FACTOR                                  46.12                 36.05                 41.99
  HC   CONCENTRATION PPM                            14.                   11.                   14.
  CO   CONCENTRATION PPM                            22.                   20.                   21.
  CO2  CONCENTRATION PCT                            .23                   .32                   .26
  NOX  CONCENTRATION PPM                           30.2                  47.8                  31.9

  HC   MASS GRAMS                                  2.25                  1.07                  2.15
  CO   MASS GRAMS                                  6.90                  6.84                  6.81
  CO2  MASS GRAMS                                1170.9                1712.5                1332.1
  NOX  MASS GRAMS                                 15.93                 26.57                 16.81
  FUEL KG (LB)                                    .375 (    .83)        .545 (   1.20)        .426 (    .94)
  KW HR (HP HR)                                   1.25 (   1.67)        2.02 (   2.71)        1.37 (   1.84)

  BSHC G/KW HR (G/HP HR)                          1.80 (   1.35)         .92 (    .69)        1.56 (   1.17)
  BSCO G/KW HR (G/HP HR)                          5.53 (   4.12)        3.38 (   2.52)        4.96 (   3.70)
  BSCO2 G/KW HR (G/HP HR)                       938.96 ( 700.18)      847.70 ( 632.13)      971.12 ( 724.17)
  BSNOX G/KW HR (G/HP HR)                        12.78 (   9.53)       13.15 (   9.81)       12.26 (   9.14)
  BSFC KG/KW HR (LB/HP HR)                        .301 (   .494)        .270 (   .444)        .310 (   .510)

TOTAL TEST RESULTS 3 BAGS                          PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)           4.64 (  6.22)          90MM FILTER
   BSHC    G/KW HR (G/HP HR)    1.35 (  1.01)            SAMPLE FLOW       SCM(SCF)                     .654 ( 23.00)
   BSCO    G/KW HR (G/HP HR)    4.43 (  3.30)            MULTIPLIER FOR    G/TEST                      1.208
   BSCO2   G/KW HR (G/HP HR)    909. (  678.)            MULTIPLIER FOR    G/KW HR (G/HP HR)            .2776 ( .2070)
   BSNOX   G/KW HR (G/HP HR)   12.79 (  9.54)            MULTIPLIER FOR    G/KG FUEL (G/LB FUEL)        .9567 ( .4340)
   BSFC  KG/KW HR (LB/HP HR)    .290 (  .477)

  PART. G/KW-HR (G/HP-HR) 0.82 (0.61)                 20 X 20 FILTERS
                                                         SAMPLE FLOW     SCM(SCF)                     56.73 (2003.6)
```

APPENDIX C

TRANSIENT TEST RESULTS FROM THE METHANOL CONFIGURATION

TABLE C-1. NOTES CONCERNING TEST RESULTS GIVEN IN APPENDIX C

Table No.	Notes
Cold Start	
C-2	Uncertain if throttle return spring was connected - this would have allowed the throttle to close slower. Passed statistical requirements. Results used for regulated emissions.
C-3	Broken throttle return spring was noted prior to run - replaced spring. Failed statistical requirements, torque intercept - 16.7 indicating that engine was being motored during idle. Results used for regulated emissions. NO_x by bag measurement was 7.52 g/kW-hr.
C-4	Failed statistical requirements, torque intercept - 17.7 Results used for regulated emissions. NO_x by bag measurement was 7.40 g/kW-hr. NO_x emission estimated to be 7.57 g/kW-hr on the basis of bag NO_x measurements.
C-5	Additional runs were made to optimize dynamometer/engine control prior to this test. Passed statistical requirements. Results used for regulated emissions. NO_x by bag measurement was 7.02 g/kW-hr.
C-6	Passed statistical requirements. Results used for regulated emissions.
C-7	This test was conducted much later for additional unregulated chemistry data and required the use of a 100K TQ meter. Results not used for regulated emissions. Failed statistical requirements, torque, and power slope were -23 and 5.2 respectively. Actual power more than 15 percent below cycle power.
C-8	Passed statistical requirements but actual power was more than 15 percent below cycle power. Results not used for regulated emissions. Particulate emission void.
Hot Start	
C-9	Same as C-2.
C-10	Passed statistical requirements. Results used for regulated emissions. NO_x bag measurement was 7.29 g/kW-hr.
C-11	Passed statistical requirements. Results used for regulated emissions. Particulate not taken. NO_x by bag measurement was 7.09 g/kW-hr. NO_x emission estimated to be 7.24 g/kW-hr on the basis of bag NO_x measurement.
C-12	Same as C-5.
C-13	Same as C-5.

TABLE C-1.(CONT'D). NOTES CONCERNING TEST RESULTS GIVEN IN APPENDIX C

Table No.	Notes
C-14	Same as C-7, but passed statistical requirements.
C-15	Same as C-7, but passed statistical requirements. Results not used for regulated emissions.
Bus Cycle	
C-16	Same as C-2. NO_x by bag measurement was 9.65 g/kW-hr.
C-17	Same as C-2. NO_x by bag measurement was 9.89 g/kW-hr.
C-18	Failed statistical requirements, torque and R^2 were low. Results used for regulated emissions. NO_x by bag measurement was 8.45 g/kW-hr.
C-19	No statistical data. Results used for regulated emissions.
C-20	Failed statistical requirements, torque R^2 1.4 percent low, Actual power more than 15 percent below cycle power. Results not used for regulated emissions. NO_x by bag measurement was 9.26 g/kW-hr.

TABLE C-2. ENGINE EMISSION RESULTS
COLD TRANSIENT

PROJECT NO. 11-5044-301

ENGINE NO.D20
ENGINE MODEL 80 VOLVO DUAL FUEL
ENGINE 9.6 L(586. CID) L-6
CVS NO. 10

TEST NO.20-1 RUN
DATE 9/22/80
TIME 11:35
DYNO NO. 5

DIESEL EM-465-F
BAG CART NO. 1

BAROMETER 740.66 MM HG(29.16 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-52. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 9.9 GM/KG(69.0 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
BLOWER DIF P MM. H2O(IN. H2O)	673.1 (26.5)	673.1 (26.5)	673.1 (26.5)	673.1 (26.5)
BLOWER INLET P MM. H2O(IN. H2O)	520.7 (20.5)	520.7 (20.5)	520.7 (20.5)	520.7 (20.5)
BLOWER INLET TEMP. DEG. C(DEG. F)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)
BLOWER REVOLUTIONS	6180.	6263.	6370.	6202.
TIME SECONDS	295.9	299.9	305.0	297.0
TOTAL FLOW STD. CU. METRES(SCF)	295.7 (10446.)	299.7 (10586.)	304.8 (10767.)	296.8 (10483.)
HC SAMPLE METER/RANGE/PPM	6.7/22/ 33.	9.0/22/ 45.	13.8/22/ 69.	5.5/22/ 27.
HC BCKGRD METER/RANGE/PPM	9.3/ 1/ 9.	7.9/ 1/ 8.	10.0/ 1/ 10.	9.5/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	71.9/12/ 165.	53.4/12/ 114.	89.6/13/ 91.	90.2/13/ 91.
CO BCKGRD METER/RANGE/PPM	.3/12/ 1.	.3/12/ 1.	.6/13/ 1.	.5/13/ 0.
CO2 SAMPLE METER/RANGE/PCT	20.7/ 3/ .33	28.3/ 3/ .47	62.6/ 3/ 1.11	18.4/ 3/ .29
CO2 BCKGRD METER/RANGE/PCT	2.9/ 3/ .04	2.7/ 3/ .04	3.1/ 3/ .05	3.1/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	8.8/13/ 26.	10.9/13/ 33.	22.4/13/ 67.	10.0/13/ 30.
NOX BCKGRD METER/RANGE/PPM	.5/ 2/ 1.	.5/ 2/ 1.	.5/ 2/ 1.	.5/ 2/ 1.
DILUTION FACTOR	37.97	27.85	11.85	43.76
HC CONCENTRATION PPM	24.	38.	60.	18.
CO CONCENTRATION PPM	160.	111.	86.	89.
CO2 CONCENTRATION PCT	.29	.43	1.07	.25
NOX CONCENTRATION PPM	25.8	32.2	66.8	29.6
HC MASS GRAMS	4.14	6.49	10.51	3.10
CO MASS GRAMS	55.12	38.64	30.67	30.59
CO2 MASS GRAMS	1572.5	2336.5	5980.9	1349.1
NOX MASS GRAMS	14.59	18.47	38.97	16.82
FUEL KG (LB)	.905 (2.00)	1.396 (3.08)	3.719 (8.20)	.754 (1.66)
KW HR (HP HR)	1.25 (1.67)	2.11 (2.83)	7.18 (9.63)	1.36 (1.83)
BSHC G/KW HR (G/HP HR)	3.32 (2.47)	3.08 (2.30)	1.46 (1.09)	2.27 (1.70)
BSCO G/KW HR (G/HP HR)	44.16 (32.93)	18.34 (13.68)	4.27 (3.19)	22.44 (16.74)
BSCO2 G/KW HR (G/HP HR)	1259.90 (939.51)	1109.05 (827.02)	833.11 (621.25)	989.67 (738.00)
BSNOX G/KW HR (G/HP HR)	11.69 (8.72)	8.77 (6.54)	5.43 (4.05)	12.34 (9.20)
BSFC KG/KW HR (LB/HP HR)	.725 (1.192)	.663 (1.090)	.518 (.852)	.553 (.909)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	11.90 (15.95)
BSHC G/KW HR (G/HP HR)	2.04 (1.52)
BSCO G/KW HR (G/HP HR)	13.03 (9.72)
BSCO2 G/KW HR (G/HP HR)	945. (704.)
BSNOX G/KW HR (G/HP HR)	7.47 (5.57)
BSFC KG/KW HR (LB/HP HR)	.569 (.936)

PART. G/KW-HR (G/HP-HR) 0.35 (0.26)

PARTICULATE DATA, TOTAL FOR 4 BAGS

90MM FILTER

SAMPLE FLOW	SCM(SCF)	1.041 (36.78)
MULTIPLIER FOR	G/TEST	1.149
MULTIPLIER FOR	G/KW HR (G/HP HR)	.0966 (.0720)
MULTIPLIER FOR	G/KG FUEL (G/LB FUEL)	.1597 (.0770)

20 X 20 FILTERS

SAMPLE FLOW	SCM(SCF)	79.92 (2822.8)

TABLE C-3. ENGINE EMISSION RESULTS
COLD TRANSIENT

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                                                                                          PROJECT NO. 11-5044-001
ENGINE   NO.D20                                TEST NO.20-2    RUN
ENGINE   MODEL    80 VOLVO DUAL FUEL           DATE  9/23/80
ENGINE   9.6 L(586. CID) L-6                   TIME 09:25                              DIESEL    EM-465-F
CVS NO.  10                                     DYNO NO.  5                             BAG CART NO.  1

BAROMETER 740.92 MM HG(29.17 IN HG)            RELATIVE HUMIDITY ,  ENGINE-50. PCT ,  CVS-55. PCT
DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)          ABSOLUTE HUMIDITY 11.1 GM/KG( 77.6 GRAINS/LB)       NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                     1                   2                   3                   4
   DESCRIPTION                                  NYNF                LANF                LAF                 NYNF
   BLOWER DIF P MM. H2O(IN. H2O)            673.1 (26.5)        673.1 (26.5)        673.1 (26.5)        673.1 (26.5)
   BLOWER INLET P MM. H2O(IN. H2O)          523.2 (20.6)        523.2 (20.6)        523.2 (20.6)        523.2 (20.6)
   BLOWER INLET TEMP. DEG. C(DEG. F)         48.9 (120.0)        48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
   BLOWER REVOLUTIONS                          6181.               6264.               6371.               6202.
   TIME SECONDS                                296.0               300.0               305.0               297.0
   TOTAL FLOW STD. CU. METRES(SCF)          296.0 (10454.)      300.0 (10594.)      305.1 (10775.)      297.0 (10489.)

   HC   SAMPLE METER/RANGE/PPM              5.8/22/  29.        8.6/22/  43.       14.1/22/  71.        5.7/22/  29.
   HC   BCKGRD METER/RANGE/PPM              8.5/ 1/   9.        8.7/ 1/   9.        9.5/ 1/  10.        9.9/ 1/  10.
   CO   SAMPLE METER/RANGE/PPM             54.2/12/ 116.       89.4/13/  90.       80.4/13/  80.       74.1/13/  73.
   CO   BCKGRD METER/RANGE/PPM               .3/12/   1.         .6/13/   1.         .7/13/   1.         .9/13/   1.
   CO2  SAMPLE METER/RANGE/PCT             18.6/ 3/  .30       24.9/ 3/  .41       58.3/ 3/ 1.03       17.0/ 3/  .27
   CO2  BCKGRD METER/RANGE/PCT              3.1/ 3/  .05        2.8/ 3/  .04        2.7/ 3/  .04        2.8/ 3/  .04
   NOX  SAMPLE METER/RANGE/PPM              9.0/13/  27.        9.5/13/  28.       20.9/13/  63.       10.1/13/  30.
   NOX  BCKGRD METER/RANGE/PPM              1.0/ 2/   1.        1.0/ 2/   1.        1.0/ 2/   1.         .9/ 2/   1.

   DILUTION FACTOR                           42.92               31.98               12.83               47.67
   HC   CONCENTRATION PPM                    21.                 35.                 62.                 19.
   CO   CONCENTRATION PPM                   113.                 87.                 77.                 71.
   CO2  CONCENTRATION PCT                    .25                 .36                 .99                 .23
   NOX  CONCENTRATION PPM                   26.2                27.4                61.8                29.5

   HC   MASS GRAMS                           3.52                5.97               10.88                3.24
   CO   MASS GRAMS                          39.02               30.56               27.26               24.50
   CO2  MASS GRAMS                        1363.8              2001.6              5537.7              1246.4
   NOX  MASS GRAMS                          14.82               15.72               36.08               16.77
   FUEL KG (LB)                            .777 (   1.71)    1.195 (   2.63)    3.444 (   7.59)     .694 (   1.53)
   KW HR (HP HR)                           1.03 (   1.38)     1.92 (   2.58)     6.68 (   8.96)     1.15 (   1.54)

   BSHC G/KW HR (G/HP HR)                  3.43 (   2.56)     3.11 (   2.32)     1.63 (   1.21)     2.82 (   2.10)
   BSCO G/KW HR (G/HP HR)                 38.00 (  28.33)    15.91 (  11.86)     4.08 (   3.04)    21.29 (  15.87)
   BSCO2 G/KW HR (G/HP HR)              1328.14 ( 990.39)  1041.99 ( 777.01)   828.59 ( 617.88)  1083.11 ( 807.68)
   BSNOX G/KW HR (G/HP HR)                14.43 (  10.76)     8.18 (   6.10)     5.40 (   4.03)    14.57 (  10.87)
   BSFC KG/KW HR (LB/HP HR)                .757 (  1.245)     .622 (  1.022)     .515 (   .847)     .603 (   .991)

TOTAL TEST RESULTS 4 BAGS                           PARTICULATE DATA, TOTAL FOR 4 BAGS

   TOTAL KW HR (HP HR)         10.78 ( 14.46)          90MM FILTER
   BSHC    G/KW HR (G/HP HR)    2.19 (  1.63)             SAMPLE FLOW     SCM(SCF)                 1.060 ( 37.45)
   BSCO    G/KW HR (G/HP HR)   11.25 (  8.39)             MULTIPLIER FOR  G/TEST                   1.130
   BSCO2   G/KW HR (G/HP HR)   941.  (  702.)             MULTIPLIER FOR  G/KW HR (G/HP HR)         .1048 ( .0781)
   BSNOX   G/KW HR (G/HP HR)    7.73 (  5.77)             MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)     .1849 ( .0839)
   BSFC   KG/KW HR (LB/HP HR)   .567 (  .932)
                                                       20 X 20 FILTERS
   PART. G/KW-HR (G/HP-HR) .44 (.33)                      SAMPLE FLOW     SCM(SCF)                80.54 (2844.8)
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TABLE C-4. ENGINE EMISSION RESULTS
COLD TRANSIENT

PROJECT NO. 11-5044-001

ENGINE NO.D20
ENGINE MODEL 80 VOLVO DUAL FUEL
ENGINE 9.6 L(586. CID) L-6
CVS NO. 10

TEST NO.20-3 RUN
DATE 9/24/80
TIME 10:35
DYNO NO. 5

DIESEL EM-465-F
BAG CART NO. 1

BAROMETER 739.90 MM HG(29.13 IN HG)
DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)

RELATIVE HUMIDITY , ENGINE-50. PCT , CVS-55. PCT
ABSOLUTE HUMIDITY 10.8 GM/KG(75.9 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS				
BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
BLOWER DIF P MM. H2O(IN. H2O)	650.2 (25.6)	650.2 (25.6)	650.2 (25.6)	650.2 (25.6)
BLOWER INLET P MM. H2O(IN. H2O)	523.2 (20.6)	523.2 (20.6)	523.2 (20.6)	523.2 (20.6)
BLOWER INLET TEMP. DEG. C(DEG. F)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)
BLOWER REVOLUTIONS	6181.	6262.	6370.	6202.
TIME SECONDS	297.0	299.0	305.0	297.0
TOTAL FLOW STD. CU. METRES(SCF)	295.6 (10441.)	299.4 (10577.)	304.6 (10759.)	296.6 (10476.)
HC SAMPLE METER/RANGE/PPM	6.0/22/ 30.	8.1/22/ 41.	13.5/22/ 67.	7.1/22/ 35.
HC BCKGRD METER/RANGE/PPM	11.2/ 1/ 11.	11.1/ 1/ 11.	12.8/ 1/ 13.	19.3/ 1/ 19.
CO SAMPLE METER/RANGE/PPM	58.8/12/ 128.	94.4/13/ 96.	84.2/13/ 85.	80.4/13/ 80.
CO BCKGRD METER/RANGE/PPM	.4/12/ 1.	1.0/13/ 1.	1.1/13/ 1.	1.5/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	19.4/ 3/ .31	25.3/ 3/ .41	58.1/ 3/ 1.03	16.5/ 3/ .26
CO2 BCKGRD METER/RANGE/PCT	3.5/ 3/ .05	3.1/ 3/ .05	2.7/ 3/ .04	2.6/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	9.5/13/ 29.	10.9/13/ 33.	25.6/13/ 77.	10.4/13/ 31.
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ 1.	.8/ 2/ 1.	.7/ 2/ 1.	.7/ 2/ 1.
DILUTION FACTOR	40.98	31.44	12.88	48.88
HC CONCENTRATION PPM	19.	30.	55.	16.
CO CONCENTRATION PPM	125.	92.	80.	77.
CO2 CONCENTRATION PCT	.26	.37	.99	.22
NOX CONCENTRATION PPM	27.8	32.0	76.1	30.6
HC MASS GRAMS	3.26	5.17	9.75	2.82
CO MASS GRAMS	42.90	32.24	28.55	26.66
CO2 MASS GRAMS	1402.8	2011.9	5507.5	1215.7
NOX MASS GRAMS	15.73	18.34	44.35	17.35
FUEL KG (LB)	.799 (1.76)	1.209 (2.67)	3.429 (7.56)	.690 (1.52)
KW HR (HP HR)	1.04 (1.39)	1.96 (2.62)	6.75 (9.06)	1.17 (1.57)
BSHC G/KW HR (G/HP HR)	3.15 (2.35)	2.64 (1.97)	1.44 (1.08)	2.41 (1.80)
BSCO G/KW HR (G/HP HR)	41.42 (30.89)	16.48 (12.29)	4.23 (3.15)	22.82 (17.02)
BSCO2 G/KW HR (G/HP HR)	1354.48 (1010.04)	1028.43 (766.90)	815.42 (608.06)	1040.43 (775.85)
BSNOX G/KW HR (G/HP HR)	15.19 (11.33)	9.38 (6.99)	6.57 (4.90)	14.85 (11.07)
BSFC KG/KW HR (LB/HP HR)	.771 (1.267)	.618 (1.016)	.508 (.835)	.591 (.971)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)		10.91 (14.64)
BSHC	G/KW HR (G/HP HR)	1.92 (1.43)
BSCO	G/KW HR (G/HP HR)	11.94 (8.91)
BSCO2	G/KW HR (G/HP HR)	929. (693.)
BSNOX	G/KW HR (G/HP HR)	8.78 (6.54)*
BSFC	KG/KW HR (LB/HP HR)	.561 (.923)

*Est. BSNO$_x$ g/kW-hr (G/hp-hr) 7.57 (5.65)
Part. G/kW-hr (G/hp-hr) .38 (.28)

PARTICULATE DATA, TOTAL FOR 4 BAGS

90MM FILTER		
SAMPLE FLOW	SCM(SCF)	1.074 (37.94)
MULTIPLIER FOR	G/TEST	1.114
MULTIPLIER FOR	G/KW HR (G/HP HR)	.1020 (.0761)
MULTIPLIER FOR	G/KG FUEL (G/LB FUEL)	.1818 (.0825)
20 X 20 FILTERS		
SAMPLE FLOW	SCM(SCF)	79.56 (2809.9)

TABLE C-5. ENGINE EMISSION RESULTS
COLD TRANSIENT

PROJECT NO. 11-5044-001

ENGINE NO.D20
ENGINE MODEL 80 VOLVO DUAL FUEL
ENGINE 9.6 L(586. CID) L-6
CVS NO. 10

TEST NO.20-1C RUN
DATE 9/29/80
TIME
DYNO NO. 5

DIESEL EM-465-F
BAG CART NO. 1

BAROMETER 739.90 MM HG(29.13 IN HG)
DRY BULB TEMP. 27.8 DEG C(82.0 DEG F)

RELATIVE HUMIDITY , ENGINE-44. PCT , CVS-60. PCT
ABSOLUTE HUMIDITY 10.4 GM/KG(72.8 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS				
BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
BLOWER DIF P MM. H2O(IN. H2O)	660.4 (26.0)	660.4 (26.0)	660.4 (26.0)	660.4 (26.0)
BLOWER INLET P MM. H2O(IN. H2O)	520.7 (20.5)	520.7 (20.5)	520.7 (20.5)	520.7 (20.5)
BLOWER INLET TEMP. DEG. C(DEG. F)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)
BLOWER REVOLUTIONS	6181.	6262.	6371.	6201.
TIME SECONDS	296.0	299.8	305.0	296.9
TOTAL FLOW STD. CU. METRES(SCF)	295.8 (10448.)	299.7 (10584.)	304.9 (10769.)	296.8 (10481.)
HC SAMPLE METER/RANGE/PPM	6.3/22/ 31.	7.9/22/ 40.	13.0/22/ 65.	5.5/22/ 27.
HC BCKGRD METER/RANGE/PPM	11.5/ 1/ 12.	11.0/ 1/ 11.	10.7/ 1/ 11.	10.9/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	56.0/12/ 121.	50.2/12/ 106.	90.9/13/ 92.	70.7/13/ 69.
CO BCKGRD METER/RANGE/PPM	.4/12/ 1.	.4/12/ 1.	.9/13/ 1.	.8/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	18.6/ 3/ .30	25.0/ 3/ .41	58.6/ 3/ 1.04	15.5/ 3/ .25
CO2 BCKGRD METER/RANGE/PCT	2.6/ 3/ .04	2.4/ 3/ .04	2.0/ 3/ .03	3.0/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	8.0/13/ 24.	9.7/13/ 29.	23.7/13/ 71.	9.0/13/ 27.
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ 1.	.5/ 2/ 1.	.5/ 2/ 1.	.5/ 2/ 1.
DILUTION FACTOR	42.83	31.76	12.75	52.42
HC CONCENTRATION PPM	20.	29.	55.	17.
CO CONCENTRATION PPM	117.	103.	88.	67.
CO2 CONCENTRATION PCT	.26	.37	1.01	.20
NOX CONCENTRATION PPM	23.3	28.6	70.6	26.6
HC MASS GRAMS	3.44	5.01	9.72	2.86
CO MASS GRAMS	40.41	35.87	31.11	23.20
CO2 MASS GRAMS	1403.8	2042.1	5623.0	1092.8
NOX MASS GRAMS	13.21	16.41	41.20	15.08
FUEL KG (LB)	.823 (1.81)	1.235 (2.72)	3.510 (7.74)	.607 (1.34)
KW HR (HP HR)	1.14 (1.53)	2.04 (2.74)	7.01 (9.40)	1.19 (1.59)
BSHC G/KW HR (G/HP HR)	3.01 (2.24)	2.45 (1.83)	1.39 (1.03)	2.41 (1.80)
BSCO G/KW HR (G/HP HR)	35.39 (26.39)	17.54 (13.08)	4.44 (3.31)	19.56 (14.59)
BSCO2 G/KW HR (G/HP HR)	1229.33 (916.71)	998.64 (744.69)	802.05 (598.09)	921.31 (687.02)
BSNOX G/KW HR (G/HP HR)	11.57 (8.63)	8.02 (5.98)	5.88 (4.38)	12.72 (9.48)
BSFC KG/KW HR (LB/HP HR)	.721 (1.185)	.604 (.993)	.501 (.823)	.512 (.842)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	11.38 (15.27)
BSHC G/KW HR (G/HP HR)	1.85 (1.38)
BSCO G/KW HR (G/HP HR)	11.47 (8.55)
BSCO2 G/KW HR (G/HP HR)	893. (666.)
BSNOX G/KW HR (G/HP HR)	7.55 (5.63)
BSFC KG/KW HR (LB/HP HR)	.542 (.892)

PART. G/KW-HR (G/HP-HR) .32 (.24)

PARTICULATE DATA, TOTAL FOR 4 BAGS

90MM FILTER		
SAMPLE FLOW	SCM(SCF)	1.109 (39.16)
MULTIPLIER FOR	G/TEST	1.080
MULTIPLIER FOR	G/KW HR (G/HP HR)	.0947 (.0707)
MULTIPLIER FOR	G/KG FUEL (G/LB FUEL)	.1749 (.0793)
20 X 20 FILTERS		
SAMPLE FLOW	SCM(SCF)	80.53 (2844.2)

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                                      TABLE C-6.  ENGINE EMISSION RESULTS
                                                     COLD TRANSIENT                                 PROJECT NO. 11-5044-001

ENGINE  NO. D20                                      TEST NO.20-2C  RUN 1
ENGINE  MODEL   8U VOLVO DUAL FUEL                   DATE  9/30/80
ENGINE  9.6 L(586. CID) L-6                          TIME 09145                        DIESEL   EM-465-F
CVS NO.  10                                            DYNO NO.  5                       BAG CART NO.  1

BAROMETER 741.93 MM HG(29.21 IN HG)                  RELATIVE HUMIDITY ,  ENGINE-57. PCT ,  CVS-61. PCT
DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)                ABSOLUTE HUMIDITY 10.5 GM/KG( 73.4 GRAINS/LB)        NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                            1                  2                   3                   4
   DESCRIPITON                                          NYNF               LANF                LAF                 NYNF
   BLOWER DIF P MM. H20(IN. H20)                   665.5 (26.2)       665.5 (26.2)        665.5 (26.2)        665.5 (26.2)
   BLOWER INLET P MM. H20(IN. H20)                 520.7 (20.5)       520.7 (20.5)        520.7 (20.5)        520.7 (20.5)
   BLOWER INLET TEMP. DEG. C(DEG. F)                48.9 (120.0)       48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
   BLOWER REVOLUTIONS                                  6181.              6263.               6370.               6203.
   TIME SECONDS                                        296.0              299.9               305.0               297.0
   TOTAL FLOW STD. CU. METRES(SCF)                 296.5 (10473.)     300.4 (10612.)      305.6 (10793.)      297.6 (10510.)

   HC   SAMPLE METER/RANGE/PPM                      6.3/22/  31.       8.6/22/  43.       13.5/22/  68.        6.0/22/  30.
   HC   BCKGRD METER/RANGE/PPM                     12.1/ 1/  12.      11.9/ 1/  12.       12.5/ 1/  13.       12.0/ 1/  12.
   CO   SAMPLE METER/RANGE/PPM                     58.2/12/ 127.      49.7/12/ 105.       91.4/13/  92.       90.7/13/  92.
   CO   BCKGRD METER/RANGE/PPM                      2.8/12/   5.       4.5/12/   8.        9.8/13/   9.        8.7/13/   8.
   CO2  SAMPLE METER/RANGE/PCT                     19.4/ 3/  .31      25.2/ 3/  .41       60.3/ 3/ 1.07       17.2/ 3/  .27
   CO2  BCKGRD METER/RANGE/PCT                      3.2/ 3/  .05       3.1/ 3/  .05        3.1/ 3/  .05        3.0/ 3/  .05
   NOX  SAMPLE METER/RANGE/PPM                      7.9/13/  24.       9.2/13/  28.       23.4/13/  70.        9.1/13/  27.
   NOX  BCKGRD METER/RANGE/PPM                       .5/ 2/   1.        .6/ 2/   1.         .8/ 2/   1.         .7/ 2/   1.

   DILUTION FACTOR                                    40.98              31.49               12.36               46.79
   HC   CONCENTRATION PPM                              20.                31.                 56.                 18.
   CO   CONCENTRATION PPM                             119.                94.                 81.                 82.
   CO2  CONCENTRATION PCT                              .26                .37                1.03                 .23
   NOX  CONCENTRATION PPM                             23.2               26.9                69.5                26.5

   HC   MASS GRAMS                                    3.35               5.45                9.87                3.10
   CO   MASS GRAMS                                   40.93              32.98               28.83               28.45
   CO2  MASS GRAMS                                  1431.7             2009.0              5737.7              1250.7
   NOX  MASS GRAMS                                   13.13              15.48               40.64               15.09
   FUEL KG (LB)                                      .862 (   1.90)    1.214 (   2.68)     3.593 (   7.92)      .711 (   1.57)
   KW HR (HP HR)                                     1.13 (   1.52)     1.99 (   2.67)      6.96 (   9.33)      1.25 (   1.67)

   BSHC G/KW HR (G/HP HR)                            2.95 (   2.20)     2.74 (   2.04)      1.42 (   1.06)      2.49 (   1.85)
   BSCO G/KW HR (G/HP HR)                           36.12 (  26.94)    16.56 (  12.35)      4.14 (   3.09)     22.80 (  17.00)
   BSCO2 G/KW HR (G/HP HR)                        1263.56 ( 942.23)  1008.67 ( 752.17)    824.65 ( 614.94)   1002.04 ( 747.22)
   BSNOX G/KW HR (G/HP HR)                          11.59 (   8.64)     7.77 (   5.80)      5.84 (   4.36)     12.09 (   9.02)
   BSFC KG/KW HR (LB/HP HR)                          .761 (  1.251)     .610 (  1.002)      .516 (   .849)      .570 (   .936)

TOTAL TEST RESULTS 4 BAGS                                 PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          11.33 ( 15.19)                 90MM FILTER
   BSHC   G/KW HR (G/HP HR)     1.92 (  1.43)                      SAMPLE FLOW      SCM(SCF)                    1.065 ( 37.62)
   BSCO   G/KW HR (G/HP HR)    11.58 (  8.63)                      MULTIPLIER FOR   G/TEST                      1.127
   BSCO2  G/KW HR (G/HP HR)     920. (  686.)                      MULTIPLIER FOR   G/KW HR (G/HP HR)            .0994 ( .0742)
   BSNOX  G/KW HR (G/HP HR)     7.44 (  5.55)                      MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)        .1766 ( .0801)
   BSFC   KG/KW HR (LB/HP HR)   .563 (  .926)
PART. G/KW-HR (G/HP-HR) .35 (.26)                             20 X 20 FILTERS
                                                                   SAMPLE FLOW     SCM(SCF)                     80.35 (2838.1)
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TABLE C-7.

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                                          ENGINE EMISSION RESULTS                                         PROJECT NO. 11-5044-001
                                                  C-TRANS.

ENGINE  NO.D20                          TEST NO.20-1C  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL       DATE 11/17/80
ENGINE  9.6 L(586. CID) L-6             TIME 03:27                                DIESEL   CM-465-F
CVS NO.  10                               DYNO NO.  5                              BAG CART NO.  1

BAROMETER 747.01 MM HG(29.41 IN HG)     RELATIVE HUMIDITY ,  ENGINE-58. PCT ,  CVS-25. PCT
DRY BULB TEMP. 20.6 DEG C(69.0 DEG F)   ABSOLUTE HUMIDITY  8.9 GM/KG( 62.2 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                   1                   2                   3                   4
   DESCRIPTION                                NYNF                LANF                 LAF                NYNF
   BLOWER DIF P MM. H2O(IN. H2O)         685.8 (27.0)        685.8 (27.0)        685.8 (27.0)        685.8 (27.0)
   BLOWER INLET P MM. H2O(IN. H2O)       530.9 (20.9)        530.9 (20.9)        530.9 (20.9)        530.9 (20.9)
   BLOWER INLET TEMP. DEG. C(DEG. F)      48.9 (120.0)        48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
   BLOWER REVOLUTIONS                       6182.               6265.               6371.               6202.
   TIME SECONDS                             296.0               299.9               305.0               296.9
   TOTAL FLOW STD. CU. METRES(SCF)       278.4 (10539.)      302.4 (10681.)      307.5 (10861.)      299.4 (10573.)

   HC   SAMPLE METER/RANGE/PPM            6.1/22/  31.        8.2/22/  41.       14.0/22/  70.        5.3/22/  27.
   HC   BCKGRD METER/RANGE/PPM            3.7/ 1/   9.        3.0/ 1/   8.        3.9/ 1/   9.        3.5/ 1/   7.
   CO   SAMPLE METER/RANGE/PPM           52.4/12/ 112.       78.0/13/  77.       68.2/13/  66.       73.7/13/  72.
   CO   BCKGRD METER/RANGE/PPM             .1/12/   0.        1.4/13/   1.        1.7/13/   2.        1.7/13/   2.
   CO2  SAMPLE METER/RANGE/PCT           18.0/ 3/  .29       24.5/ 3/  .40       56.2/ 3/  .99       16.2/ 3/  .26
   CO2  BCKGRD METER/RANGE/PCT            1.7/ 3/  .03        3.0/ 3/  .05        3.0/ 3/  .05        2.7/ 3/  .04
   NOX  SAMPLE METER/RANGE/PPM            5.9/13/  18.        7.1/13/  21.       20.5/13/  61.        8.1/13/  24.
   NOX  BCKGRD METER/RANGE/PPM             .3/ 2/   0.         .3/ 2/   0.         .3/ 2/   0.         .3/ 2/   0.

   DILUTION FACTOR                          44.38               32.64               13.30               50.09
   HC   CONCENTRATION PPM                   22.                 33.                 62.                 18.
   CO   CONCENTRATION PPM                  110.                 75.                 63.                 70.
   CO2  CONCENTRATION PCT                    .26                 .35                 .95                 .21
   NOX  CONCENTRATION PPM                   17.5                21.0                61.2                24.0

   HC   MASS GRAMS                           3.81                5.77               10.97                3.17
   CO   MASS GRAMS                          38.29               26.24               22.56               24.32
   CO2  MASS GRAMS                        1434.6              1962.7              5323.9              1174.7
   NOX  MASS GRAMS                          10.00               12.16               36.00               13.75
   FUEL KG (LB)                            .830 (   1.83)    1.155 (   2.55)    3.268 (   7.20)     .654 (   1.44)
   KW HR (HP HR)                           1.03 (   1.38)     1.80 (   2.42)     6.36 (   8.52)     1.07 (   1.44)

   BSHC G/KW HR (G/HP HR)                  3.71 (   2.76)     3.20 (   2.38)     1.73 (   1.29)     2.95 (   2.20)
   BSCO G/KW HR (G/HP HR)                 37.25 (  27.78)    14.55 (  10.85)     3.55 (   2.65)    22.66 (  16.90)
   BSCO2 G/KW HR (G/HP HR)              1395.61 (1040.70)  1088.32 ( 811.56)   837.50 ( 624.53)  1094.75 ( 816.36)
   BSNOX G/KW HR (G/HP HR)                 9.72 (   7.25)     6.75 (   5.03)     5.66 (   4.22)    12.81 (   9.55)
   BSFC KG/KW HR (LB/HP HR)                .807 (  1.327)     .640 (  1.053)     .514 (   .845)     .609 (  1.001)

TOTAL TEST RESULTS 4 BAGS                             PARTICULATE DATA, TOTAL FOR 4 BAGS

   TOTAL KW HR (HP HR)          10.26 ( 13.76)          70MM FILTER
    BSHC   G/KW HR (G/HP HR)     2.31 (  1.72)              SAMPLE FLOW      SCM(SCF)                     1.286 ( 45.43)
    BSCO   G/KW HR (G/HP HR)    10.86 (  8.10)              MULTIPLIER FOR   G/TEST                        .939
    BSCO2  G/KW HR (G/HP HR)    964.  (  719.)              MULTIPLIER FOR   G/KW HR (G/HP HR)             .0915 ( .0682)
    BSNOX  G/KW HR (G/HP HR)     7.01 (  5.23)              MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)         .1590 ( .0721)
    BSFC  KG/KW HR (LB/HP HR)    .576 (  .946)
                                                         20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR) .39 (.29)                           SAMPLE FLOW      SCM(SCF)                     81.43 (2876.0)
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TABLE C-8. ENGINE EMISSION RESULTS
HOT TRANSIENT

PROJECT NO. 11-5044-001

ENGINE NO.020
ENGINE MODEL 80 VOLVO DUAL FUEL
ENGINE 9.6 L(586. CID) L-6
CVS NO. 10

TEST NO.20-1 RUN 1
DATE 9/22/80
TIME 12:17
DYNO NO. 5

DIESEL EM-465-F
BAG CART NO. 1

BAROMETER 740.66 MM HG(29.16 IN HG)
DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)

RELATIVE HUMIDITY , ENGINE-46. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 10.3 GM/KG(72.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0300

BAG RESULTS				
BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
BLOWER DIF P MM. H2O(IN. H2O)	650.2 (25.6)	650.2 (25.6)	650.2 (25.6)	650.2 (25.6)
BLOWER INLET P MM. H2O(IN. H2O)	523.2 (20.6)	523.2 (20.6)	523.2 (20.6)	523.2 (20.6)
BLOWER INLET TEMP. DEG. C(DEG. F)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)
BLOWER REVOLUTIONS	6182.	6264.	6370.	6202.
TIME SECONDS	296.0	300.0	305.0	296.9
TOTAL FLOW STD. CU. METRES(SCF)	296.1 (10460.)	300.1 (10598.)	305.1 (10778.)	297.1 (10493.)
HC SAMPLE METER/RANGE/PPM	5.9/22/ 30.	8.1/22/ 40.	13.4/22/ 67.	5.7/22/ 28.
HC BCKGRD METER/RANGE/PPM	10.0/ 1/ 10.	9.7/ 1/ 10.	9.7/ 1/ 10.	10.0/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	92.5/13/ 94.	50.7/12/ 108.	92.2/13/ 93.	90.8/13/ 92.
CO BCKGRD METER/RANGE/PPM	.7/13/ 1.	.3/12/ 1.	.6/13/ 1.	.6/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	18.1/ 3/ .29	28.3/ 3/ .47	62.6/ 3/ 1.11	18.9/ 3/ .30
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .05	3.4/ 3/ .05	3.4/ 3/ .05	3.1/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	8.4/13/ 25.	10.9/13/ 33.	21.5/13/ 64.	9.5/13/ 29.
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ 1.	.7/ 2/ 1.	.6/ 2/ 1.	.6/ 2/ 1.
DILUTION FACTOR	44.42	27.92	11.85	42.57
HC CONCENTRATION PPM	20.	31.	58.	19.
CO CONCENTRATION PPM	91.	104.	89.	89.
CO2 CONCENTRATION PCT	.24	.42	1.07	.26
NOX CONCENTRATION PPM	24.4	32.0	63.9	27.9
HC MASS GRAMS	3.40	5.36	10.19	3.19
CO MASS GRAMS	31.32	36.39	31.67	30.81
CO2 MASS GRAMS	1318.7	2281.9	5963.2	1396.5
NOX MASS GRAMS	13.83	18.38	37.30	15.87
FUEL KG (LB)	.718 (1.58)	1.310 (2.89)	3.656 (8.06)	.782 (1.73)
KW HR (HP HR)	1.28 (1.72)	2.22 (2.98)	7.15 (9.59)	1.36 (1.83)
BSHC G/KW HR (G/HP HR)	2.65 (1.97)	2.41 (1.80)	1.43 (1.06)	2.34 (1.74)
BSCO G/KW HR (G/HP HR)	24.40 (18.19)	16.38 (12.21)	4.43 (3.30)	22.60 (16.86)
BSCO2 G/KW HR (G/HP HR)	1027.36 (766.10)	1027.04 (765.86)	833.72 (621.71)	1024.42 (763.91)
BSNOX G/KW HR (G/HP HR)	10.78 (8.04)	8.27 (6.17)	5.21 (3.89)	11.65 (8.68)
BSFC KG/KW HR (LB/HP HR)	.559 (.920)	.589 (.969)	.511 (.840)	.574 (.944)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	12.02 (16.12)
BSHC G/KW HR (G/HP HR)	1.84 (1.37)
BSCO G/KW HR (G/HP HR)	10.83 (8.08)
BSCO2 G/KW HR (G/HP HR)	912. (680.)
BSNOX G/KW HR (G/HP HR)	7.10 (5.30)
BSFC KG/KW HR (LB/HP HR)	.538 (.884)

PART. G/KW-HR (G/HP-HR) .39 (.29)

PARTICULATE DATA, TOTAL FOR 4 BAGS

90MM FILTER		
SAMPLE FLOW	SCM(SCF)	1.054 (37.23)
MULTIPLIER FOR	G/TEST	1.137
MULTIPLIER FOR	G/KW HR (G/HP HR)	.0946 (.0705)
MULTIPLIER FOR	G/KG FUEL (G/LB FUEL)	.1758 (.0798)
20 X 20 FILTERS		
SAMPLE FLOW	SCM(SCF)	80.37 (2838.5)

TABLE C-9. ENGINE EMISSION RESULTS
HOT TRANSIENT

PROJECT NO. 11-5044-001

ENGINE NO.D20
ENGINE MODEL 80 VOLVO DUAL FUEL
ENGINE 9.6 L(586. CID) L-6
CVS NO. 10

TEST NO.20-2 RUN 1
DATE 9/23/80
TIME 10:05
DYNO NO. 5

DIESEL EM-465-F
BAG CART NO. 1

BAROMETER 740.92 MM HG(29.17 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY , ENGINE-50. PCT , CVS-52. PCT
ABSOLUTE HUMIDITY 10.5 GM/KG(73.3 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS				
BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
BLOWER DIF P MM. H2O(IN. H2O)	650.2 (25.6)	650.2 (25.6)	650.2 (25.6)	650.2 (25.6)
BLOWER INLET P MM. H2O(IN. H2O)	523.2 (20.6)	523.2 (20.6)	523.2 (20.6)	523.2 (20.6)
BLOWER INLET TEMP. DEG. C(DEG. F)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)	48.9 (120.0)
BLOWER REVOLUTIONS	6181.	6262.	6370.	6202.
TIME SECONDS	296.0	299.9	305.0	297.0
TOTAL FLOW STD. CU. METRES(SCF)	296.2 (10463.)	300.1 (10600.)	305.3 (10783.)	297.2 (10498.)
HC SAMPLE METER/RANGE/PPM	6.1/22/ 30.	7.7/22/ 39.	13.3/22/ 66.	5.6/22/ 28.
HC BCKGRD METER/RANGE/PPM	9.6/ 1/ 10.	9.0/ 1/ 9.	8.5/ 1/ 9.	9.0/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	67.2/13/ 66.	82.8/13/ 83.	81.6/13/ 82.	74.6/13/ 74.
CO BCKGRD METER/RANGE/PPM	.6/13/ 1.	.4/13/ 0.	.6/13/ 1.	.6/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	15.8/ 3/ .25	23.6/ 3/ .38	56.6/ 3/ 1.00	16.4/ 3/ .26
CO2 BCKGRD METER/RANGE/PCT	2.3/ 3/ .04	2.4/ 3/ .04	2.6/ 3/ .04	2.7/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	9.0/13/ 27.	9.3/13/ 28.	19.8/13/ 59.	9.7/13/ 29.
NOX BCKGRD METER/RANGE/PPM	.8/ 2/ 1.	.7/ 2/ 1.	.7/ 2/ 1.	.8/ 2/ 1.
DILUTION FACTOR	51.43	33.90	13.26	49.43
HC CONCENTRATION PPM	21.	30.	58.	19.
CO CONCENTRATION PPM	64.	81.	78.	72.
CO2 CONCENTRATION PCT	.22	.35	.96	.22
NOX CONCENTRATION PPM	26.2	27.3	58.7	28.5
HC MASS GRAMS	3.59	5.18	10.30	3.27
CO MASS GRAMS	21.97	28.18	27.81	24.82
CO2 MASS GRAMS	1175.4	1911.2	5361.4	1201.0
NOX MASS GRAMS	14.86	15.65	34.28	16.18
FUEL KG (LB)	.657 (1.45)	1.137 (2.51)	3.320 (7.32)	.674 (1.49)
KW HR (HP HR)	1.06 (1.42)	1.96 (2.62)	6.65 (8.92)	1.14 (1.53)
BSHC G/KW HR (G/HP HR)	3.38 (2.52)	2.65 (1.97)	1.55 (1.15)	2.86 (2.13)
BSCO G/KW HR (G/HP HR)	20.69 (15.43)	14.41 (10.74)	4.18 (3.12)	21.74 (16.21)
BSCO2 G/KW HR (G/HP HR)	1106.49 (825.11)	976.92 (728.49)	806.48 (601.39)	1051.74 (784.29)
BSNOX G/KW HR (G/HP HR)	13.98 (10.43)	8.00 (5.97)	5.16 (3.85)	14.17 (10.56)
BSFC KG/KW HR (LB/HP HR)	.619 (1.017)	.581 (.955)	.499 (.821)	.590 (.970)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	10.81 (14.49)
BSHC G/KW HR (G/HP HR)	2.07 (1.54)
BSCO G/KW HR (G/HP HR)	9.51 (7.09)
BSCO2 G/KW HR (G/HP HR)	893. (666.)
BSNOX G/KW HR (G/HP HR)	7.49 (5.59)
BSFC KG/KW HR (LB/HP HR)	.535 (.880)

PART. G/KW-HR (G/HP-HR) .46 (.34)

PARTICULATE DATA, TOTAL FOR 4 BAGS

90MM FILTER		
SAMPLE FLOW	SCM(SCF)	1.109 (39.17)
MULTIPLIER FOR	G/TEST	1.081
MULTIPLIER FOR	G/KW HR (G/HP HR)	.1000 (.0746)
MULTIPLIER FOR	G/KG FUEL (G/LB FUEL)	.1868 (.0847)
20 X 20 FILTERS		
SAMPLE FLOW	SCM(SCF)	80.44 (2841.2)

TABLE C-10.

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                                                  ENGINE EMISSION RESULTS
                                                      HOT TRANSIENT                                  PROJECT NO. 11-5044-001

ENGINE   NO.D20                                   TEST NO.20-2    RUN 2
ENGINE   MODEL    80 VOLVO DUAL FUEL              DATE  9/23/80
ENGINE   9.6 L(586. CID) L-6                      TIME 10:45                          DIESEL    EM-465-F
CVS NO.   10                                       DYNO NO.  5                          BAG CART NO.  1

BAROMETER 740.92 MM HG(29.17 IN HG)               RELATIVE HUMIDITY ,  ENGINE-51. PCT ,  CVS-58. PCT
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)             ABSOLUTE HUMIDITY 10.7 GM/KG( 74.8 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                          1                    2                    3                    4
  DESCRIPTION                                        NYNF                 LANF                 LAF                  NYNF
  BLOWER DIF P MM. H2O(IN. H2O)                 647.7 (25.5)         647.7 (25.5)         647.7 (25.5)         647.7 (25.5)
  BLOWER INLET P MM. H2O(IN. H2O)               523.2 (20.6)         523.2 (20.6)         523.2 (20.6)         523.2 (20.6)
  BLOWER INLET TEMP. DEG. C(DEG. F)              48.9 (120.0)         48.9 (120.0)         48.9 (120.0)         48.9 (120.0)
  BLOWER REVOLUTIONS                                6181.                6265.                6370.                6201.
  TIME SECONDS                                      296.0                300.0                305.0                297.0
  TOTAL FLOW STD. CU. METRES(SCF)               295.8 (10447.)       299.8 (10589.)       304.8 (10767.)       296.7 (10481.)

  HC   SAMPLE METER/RANGE/PPM                   5.8/22/  29.         7.7/22/  38.        13.2/22/  66.         5.4/22/  27.
  HC   BCKGRD METER/RANGE/PPM                   7.9/ 1/   8.         7.6/ 1/   8.         8.0/ 1/   8.         7.8/ 1/   8.
  CO   SAMPLE METER/RANGE/PPM                  67.5/13/  66.        82.5/13/  83.        82.0/13/  82.        75.2/13/  74.
  CO   BCKGRD METER/RANGE/PPM                    .6/13/   1.          .4/13/   0.          .2/13/   0.          .5/13/   0.
  CO2  SAMPLE METER/RANGE/PCT                  16.3/ 3/  .26        24.0/ 3/  .39        57.2/ 3/ 1.01        16.7/ 3/  .27
  CO2  BCKGRD METER/RANGE/PCT                   3.1/ 3/  .05         3.2/ 3/  .05         3.1/ 3/  .05         3.0/ 3/  .05
  NOX  SAMPLE METER/RANGE/PPM                   6.2/13/  19.         7.1/13/  21.        15.8/13/  47.         7.5/13/  23.
  NOX  BCKGRD METER/RANGE/PPM                    .8/ 2/   1.          .8/ 2/   1.         1.0/ 2/   1.          .8/ 2/   1.

  DILUTION FACTOR                                  49.86                33.32                13.11                48.54
  HC   CONCENTRATION PPM                           21.                  31.                  58.                  20.
  CO   CONCENTRATION PPM                           64.                  80.                  79.                  72.
  CO2  CONCENTRATION PCT                            .21                  .34                  .96                  .22
  NOX  CONCENTRATION PPM                           17.9                 20.4                 46.4                 21.8

  HC   MASS GRAMS                                   3.66                 5.37                10.28                 3.34
  CO   MASS GRAMS                                  22.00                27.98                27.97                24.98
  CO2  MASS GRAMS                                1153.3               1881.7               5379.9               1201.7
  NOX  MASS GRAMS                                  10.13                11.70                27.05                12.35
  FUEL KG (LB)                                   .696 (   1.53)     1.120 (   2.47)     3.323 (   7.33)      .678 (   1.49)
  KW HR (HP HR)                                  1.05 (   1.41)      1.96 (   2.62)      6.64 (   8.90)      1.13 (   1.52)

  BSHC G/KW HR (G/HP HR)                         3.47 (   2.59)      2.74 (   2.05)      1.55 (   1.15)      2.95 (   2.20)
  BSCC G/KW HR (G/HP HR)                        20.89 (  15.58)     14.30 (  10.66)      4.21 (   3.14)     22.05 (  16.44)
  BSCO2 G/KW HR (G/HP HR)                     1094.88 ( 816.45)    961.84 ( 717.24)    810.34 ( 604.27)   1060.56 ( 790.86)
  BSNOX G/KW HR (G/HP HR)                        9.61 (   7.17)      5.98 (   4.46)      4.07 (   3.04)     10.90 (   8.13)
  BSFC KG/KW HR (LB/HP HR)                       .660 (  1.086)      .572 (   .941)      .501 (   .823)      .598 (   .983)

TOTAL TEST RESULTS 4 BAGS                                   PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)            10.78 ( 14.46)                 90MM FILTER
   BSHC    G/KW HR (G/HP HR)      2.10 (  1.57)                   SAMPLE FLOW      SCM(SCF)                  0.000 (  0.00)
   BSCO    G/KW HR (G/HP HR)      9.55 (  7.12)                   MULTIPLIER FOR   G/TEST                    0.000
   BSCO2   G/KW HR (G/HP HR)      892. (  665.)                   MULTIPLIER FOR   G/KW HR (G/HP HR)         0.0000 (0.0000)
   BSNOX   G/KW HR (G/HP HR)      5.68 (  4.23)                   MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)     0.0000 (0.0000)
   BSFC   KG/KW HR (LB/HP HR)     .539 (  .887)
                                                                20 X 20 FILTERS
                                                                  SAMPLE FLOW      SCM(SCF)                  79.68 (2814.2)
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PART. G/KW-HR (G/HP-HR)

*Est. BSNOX g/kW-hr (G/hp-hr) 7.24 (5.40)

TABLE C-11. ENGINE EMISSION RESULTS

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                                              HOT TRANSIENT                                     PROJECT NO. 11-5044-001

ENGINE  NO.D23                                TEST NO.20-1H  RUN 1
ENGINE  MODEL   80 VOLVO DUAL FUEL            DATE  9/29/80
ENGINE  9.6 L(586. CID) L-6                   TIME 11:20                              DIESEL   EM-465-F
CVS NO.  10                                    DYNO NO.  5                             BAG CART NO.  1

BAROMETER 739.65 MM HG(29.12 IN HG)           RELATIVE HUMIDITY ,  ENGINE-50. PCT ,  CVS-57. PCT
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)         ABSOLUTE HUMIDITY 10.2 GM/KG( 71.1 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                       1                 2                  3                  4
  DESCRIPTION                                     NYNF              LANF               LAF                NYNF
  BLOWER DIF P MM. H2O(IN. H2O)               660.4 (26.0)      660.4 (26.0)       660.4 (25.0)       660.4 (26.0)
  BLOWER INLET P MM. H2O(IN. H2O)             520.7 (20.5)      520.7 (20.5)       520.7 (20.5)       520.7 (20.5)
  BLOWER INLET TEMP. DEG. C(DEG. F)            48.9 (120.0)      48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                             6182.             6263.              6369.              6200.
  TIME SECONDS                                   296.0             299.9              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)             295.5 (10437.)    299.4 (10574.)     304.4 (10753.)     296.4 (10468.)

  HC  SAMPLE METER/RANGE/PPM                   6.7/22/  33.      7.7/22/  38.      13.1/22/  65.       6.0/22/  30.
  HC  BCKGRD METER/RANGE/PPM                  13.0/ 1/  13.     12.0/ 1/  12.      12.8/ 1/  13.      11.9/ 1/  12.
  CO  SAMPLE METER/RANGE/PPM                  85.2/13/  86.     91.7/13/  93.      84.1/13/  84.      80.8/13/  81.
  CO  BCKGRD METER/RANGE/PPM                    .4/13/   0.       .5/13/   0.        .7/13/   1.        .7/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                  16.1/ 3/  .26     23.5/ 3/  .38      56.2/ 3/  .99      16.1/ 3/  .26
  CO2 BCKGRD METER/RANGE/PCT                   2.7/ 3/  .04      2.8/ 3/  .04       3.0/ 3/  .05       3.0/ 3/  .05
  NOX SAMPLE METER/RANGE/PPM                   8.0/13/  24.      9.1/13/  27.      23.2/13/  70.       8.8/13/  26.
  NOX BCKGRD METER/RANGE/PPM                   1.2/ 2/   1.      1.4/ 2/   1.       1.7/ 2/   2.       1.7/ 2/   2.

  DILUTION FACTOR                               50.04             33.97              13.37              50.20
  HC  CONCENTRATION PPM                         21.               27.                54.                18.
  CO  CONCENTRATION PPM                         83.               90.                81.                78.
  CO2 CONCENTRATION PCT                         .22               .34                .95                .21
  NOX CONCENTRATION PPM                         22.9              26.0               68.0               24.7

  HC  MASS GRAMS                                3.51              4.62               9.40               3.10
  CO  MASS GRAMS                               28.67             31.38              28.61              27.01
  CO2 MASS GRAMS                              1166.9            1864.2             5270.8             1145.7
  NOX MASS GRAMS                               12.95             14.90              39.59              13.98
  FUEL KG (LB)                                 .664 (   1.46)   1.123 (   2.48)    3.291 (   7.26)     .654 (   1.44)
  KW HR (HP HR)                                1.14 (   1.53)    2.08 (   2.79)     6.97 (   9.34)     1.22 (   1.64)

  BSHC G/KW HR (G/HP HR)                       3.07 (   2.29)    2.22 (   1.66)     1.35 (   1.01)     2.54 (   1.89)
  BSCO G/KW HR (G/HP HR)                      25.10 (  18.72)   15.08 (  11.25)     4.11 (   3.06)    22.11 (  16.49)
  BSCO2 G/KW HR (G/HP HR)                   1021.89 ( 762.02)  896.14 ( 668.25)   756.58 ( 564.18)   937.87 ( 699.37)
  BSNOX G/KW HR (G/HP HR)                     11.34 (   8.46)    7.16 (   5.34)     5.68 (   4.24)    11.44 (   8.53)
  BSFC KG/KW HR (LB/HP HR)                     .582 (   .957)    .540 (   .887)     .472 (   .777)     .535 (   .880)

TOTAL TEST RESULTS 4 BAGS                                 PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          11.41 ( 15.30)              90MM FILTER
   BSHC    G/KW HR (G/HP HR)    1.81 (  1.35)                  SAMPLE FLOW      SCM(SCF)                    1.102 ( 38.93)
   BSCO    G/KW HR (G/HP HR)   10.14 (  7.56)                  MULTIPLIER FOR   G/TEST                      1.085
   BSCO2   G/KW HR (G/HP HR)   828.  (  617.)                  MULTIPLIER FOR   G/KW HR (G/HP HR)           .0951 ( .0709)
   BSNOX   G/KW HR (G/HP HR)    7.13 (  5.32)                  MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)       .1892 ( .0858)
   BSFC   KG/KW HR (LB/HP HR)   .502 (  .826)
                                                           20 X 20 FILTERS
 PART. G/KW-HR (G/HP-HR) .38 (.28)                            SAMPLE FLOW     SCM(SCF)                    79.55 (2809.9)
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TABLE C-12.

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                                   ENGINE EMISSION RESULTS
                                        HOT TRANSIENT                              PROJECT NO. 11-5044-001
ENGINE  NO.D20
ENGINE  MODEL    80 VOLVO DUAL FUEL           TEST NO.20-2H  RUN 2
ENGINE  9.6 L(586. CID) L-6                   DATE  9/29/80
CVS NO.  10                                   TIME
                                                                                 DIESEL   EM-465-F
                                                DYNO NO.  5                        BAG CART NO.  1
BAROMETER 739.65 MM HG(29.12 IN HG)
DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)         RELATIVE HUMIDITY ,  ENGINE-48. PCT ,  CVS-57. PCT
                                              ABSOLUTE HUMIDITY 10.5 GM/KG( 73.2 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000
BAG RESULTS
  BAG NUMBER                                        1                  2                  3                  4
  DESCRIPTION                                     NYNF               LANF                LAF               NYNF
  BLOWER DIF P MM. H2O(IN. H2O)             660.4 (26.0)       660.4 (26.0)       660.4 (26.0)       660.4 (26.0)
  BLOWER INLET P MM. H2O(IN. H2O)           518.2 (20.4)       518.2 (20.4)       518.2 (20.4)       518.2 (20.4)
  BLOWER INLET TEMP. DEG. C(DEG. F)          48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                            6180.              6261.              6369.              6200.
  TIME SECONDS                                  296.0              299.9              305.0              296.9
  TOTAL FLOW STD. CU. METRES(SCF)           295.3 (10430.)     299.2 (10566.)     304.3 (10749.)     296.2 (10463.)

  HC  SAMPLE METER/RANGE/PPM                6.1/22/  30.       7.5/22/  38.      12.9/22/  64.       5.8/22/  29.
  HC  BCKGRD METER/RANGE/PPM               10.6/ 1/  11.       9.9/ 1/  10.       9.4/ 1/   9.       9.0/ 1/   9.
  CO  SAMPLE METER/RANGE/PPM               83.7/13/  84.      89.0/13/  90.      84.7/13/  85.      81.5/13/  82.
  CO  BCKGRD METER/RANGE/PPM                 .7/13/   1.        .8/13/   1.        .6/13/   1.        .6/13/   1.
  CO2 SAMPLE METER/RANGE/PCT               16.2/ 3/  .26      23.8/ 3/  .39      57.5/ 3/ 1.01      17.1/ 3/  .27
  CO2 BCKGRD METER/RANGE/PCT                3.0/ 3/  .05       3.1/ 3/  .05       3.1/ 3/  .05       3.4/ 3/  .05
  NOX SAMPLE METER/RANGE/PPM                8.1/13/  24.       9.5/13/  28.      23.4/13/  70.       9.1/13/  27.
  NOX BCKGRD METER/RANGE/PPM                1.2/ 2/   1.       1.1/ 2/   1.       1.0/ 2/   1.       1.0/ 2/   1.

  DILUTION FACTOR                             49.82              33.56              13.03              47.25
  HC  CONCENTRATION PPM                        20.                28.                56.                20.
  CO  CONCENTRATION PPM                        81.                87.                81.                79.
  CO2 CONCENTRATION PCT                        .21                .34                .97                .22
  NOX CONCENTRATION PPM                       23.2               27.3               69.3               26.2

  HC  MASS GRAMS                              3.41               4.85               9.79               3.43
  CO  MASS GRAMS                             28.00              30.26              28.85              27.29
  CO2 MASS GRAMS                            1150.6             1866.8             5403.9             1203.2
  NOX MASS GRAMS                             13.10              15.63              40.36              14.86
  FUEL KG (LB)                              .657 (   1.45)   1.120 (   2.47)   3.366 (   7.42)    .684 (   1.51)
  KW HR (HP HR)                             1.16 (   1.56)    2.02 (   2.71)    6.92 (   9.28)    1.21 (   1.63)

  BSHC G/KW HR (G/HP HR)                    2.94 (   2.19)    2.40 (   1.79)    1.41 (   1.05)    2.82 (   2.11)
  BSCO G/KW HR (G/HP HR)                   24.15 (  18.01)   14.99 (  11.18)    4.17 (   3.11)   22.50 (  16.78)
  BSCO2 G/KW HR (G/HP HR)                 992.20 ( 739.88)  924.93 ( 689.72)  780.65 ( 582.13)  992.13 ( 739.83)
  BSNOX G/KW HR (G/HP HR)                  11.30 (   8.43)    7.74 (   5.77)    5.83 (   4.35)   12.26 (   9.14)
  BSFC KG/KW HR (LB/HP HR)                  .567 (   .931)    .555 (   .913)    .486 (   .799)    .564 (   .927)

TOTAL TEST RESULTS 4 BAGS                          PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)           11.31 ( 15.17)          90MM FILTER
   BSHC   G/KW HR (G/HP HR)      1.90 (  1.42)              SAMPLE FLOW       SCM(SCF)                  1.076 ( 37.99)
   BSCO   G/KW HR (G/HP HR)     10.11 (  7.54)              MULTIPLIER FOR  G/TEST                      1.111
   BSCO2  G/KW HR (G/HP HR)     851. (  634.)               MULTIPLIER FOR  G/KW HR (G/HP HR)            .0982 ( .0732)
   BSNOX  G/KW HR (G/HP HR)      7.42 (  5.53)              MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)        .1906 ( .0865)
   BSFC  KG/KW HR (LB/HP HR)     .515 (  .847)
                                                         20 X 20 FILTERS
                                                            SAMPLE FLOW     SCM(SCF)                    78.80 (2783.3)
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PART. G/KW-HR (G/HP-HR) .39 (.29)

TABLE C-13. ENGINE EMISSION RESULTS

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                                            C-TRANS.                                  PROJECT NO. 11-5044-001

ENGINE  NO.D20                              TEST NO.D20-2  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL          DATE 11/18/80
ENGINE  9.6 L(586. CID) L-6                 TIME                                DIESEL   EM-465-F
CVS NO.  10                                   DYNO NO.  5                        BAG CART NO.  1

BAROMETER 752.09 MM HG(29.61 IN HG)         RELATIVE HUMIDITY ,  ENGINE-53. PCT ,  CVS-20. PCT
DRY BULB TEMP. 17.2 DEG C(63.0 DEG F)       ABSOLUTE HUMIDITY  6.5 GM/KG( 45.7 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                        1                 2                 3                 4
  DESCRIPTION                                     NYNF              LANF              LAF               NYNF
  BLOWER DIF P MM. H2O(IN. H2O)              685.8 (27.0)      685.8 (27.0)      685.8 (27.0)      685.8 (27.0)
  BLOWER INLET P MM. H2O(IN. H2O)            530.9 (20.9)      530.9 (20.9)      530.9 (20.9)      530.9 (20.9)
  BLOWER INLET TEMP. DEG. C(DEG. F)           48.9 (120.0)      48.9 (120.0)      48.9 (120.0)      48.9 (120.0)
  BLOWER REVOLUTIONS                           6181.             6266.             6372.             6202.
  TIME SECONDS                                 296.0             300.0             305.0             296.9
  TOTAL FLOW STD. CU. METRES(SCF)            300.9 (10628.)    305.1 (10774.)    310.2 (10957.)    301.9 (10664.)

  HC   SAMPLE METER/RANGE/PPM                 9.1/22/  46.      8.6/22/  43.     14.4/22/  72.      5.8/22/  29.
  HC   BCKGRD METER/RANGE/PPM                 9.6/ 1/  10.      9.8/ 1/  10.     11.0/ 1/  11.     10.2/ 1/  10.
  CO   SAMPLE METER/RANGE/PPM                71.9/13/  70.     72.8/13/  71.     62.3/13/  60.     67.1/13/  65.
  CO   BCKGRD METER/RANGE/PPM                  .6/13/   1.       .5/13/   0.       .6/13/   1.       .5/13/   0.
  CO2  SAMPLE METER/RANGE/PCT                17.7/ 3/  .28     24.6/ 3/  .40     55.3/ 3/  .97     16.4/ 3/  .26
  CO2  BCKGRD METER/RANGE/PCT                 3.8/ 3/  .06      3.1/ 3/  .05      3.1/ 3/  .05      3.2/ 3/  .05
  NOX  SAMPLE METER/RANGE/PPM                 6.8/13/  20.      8.1/13/  24.     22.2/13/  67.      8.3/13/  25.
  NOX  BCKGRD METER/RANGE/PPM                  .2/ 2/   0.       .1/ 2/   0.       .2/ 2/   0.       .1/ 2/   0.

  DILUTION FACTOR                              45.53             32.53             13.63             49.55
  HC   CONCENTRATION PPM                        36.               33.               62.               17.
  CO   CONCENTRATION PPM                        69.               70.               58.               64.
  CO2  CONCENTRATION PCT                        .23               .35               .93               .21
  NOX  CONCENTRATION PPM                       20.1              24.2              66.5              24.9

  HC   MASS GRAMS                               6.31              5.89             11.02              3.33
  CO   MASS GRAMS                              24.13             24.78             20.71             22.44
  CO2  MASS GRAMS                             1244.4            1981.2            5261.8            1178.2
  NOX  MASS GRAMS                              11.56             14.14             39.48             14.40
  FUEL KG (LB)                                 .754 (   1.66)   1.176 (   2.59)   3.238 (   7.14)    .648 (   1.43)
  KW HR (HP HR)                                1.00 (   1.34)    1.87 (   2.50)    6.42 (   8.61)    1.09 (   1.46)

  BSHC G/KW HR (G/HP HR)                       6.30 (   4.70)    3.15 (   2.35)    1.72 (   1.28)    3.05 (   2.27)
  BSCO G/KW HR (G/HP HR)                      24.10 (  17.97)   13.28 (   9.90)    3.26 (   2.43)   20.57 (  15.34)
  BSCO2 G/KW HR (G/HP HR)                   1243.27 ( 927.11) 1061.48 ( 791.54)  819.58 ( 611.16) 1079.85 ( 805.24)
  BSNOX G/KW HR (G/HP HR)                     11.55 (   8.62)    7.58 (   5.65)    6.15 (   4.59)   13.20 (   9.84)
  BSFC KG/KW HR (LB/HP HR)                     .753 (  1.239)    .630 (  1.036)    .504 (   .829)    .594 (   .977)

TOTAL TEST RESULTS 4 BAGS                        PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          10.38 ( 13.92)       90MM FILTER
   BSHC   G/KW HR (G/HP HR)     2.56 (  1.91)          SAMPLE FLOW      SCM(SCF)                 1.332 ( 47.03)
   BSCO   G/KW HR (G/HP HR)     8.89 (  6.63)          MULTIPLIER FOR   G/TEST                    .915
   BSCO2  G/KW HR (G/HP HR)     731. (  674.)          MULTIPLIER FOR   G/KW HR (G/HP HR)         .0881 ( .0657)
   BSNOX  G/KW HR (G/HP HR)     7.67 (  5.72)          MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)     .1573 ( .0713)
   BSFC  KG/KW HR (LB/HP HR)    .560 (  .921)
                                                    20 X 20 FILTERS
PART.          VOID                                    SAMPLE FLOW      SCM(SCF)                 83.49 (2948.8)
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TABLE C-14. ENGINE EMISSION RESULTS

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                                          H-TRANS.                                          PROJECT NO. 11-5044-001

ENGINE  NO.D20                                   TEST NO.D20-1  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL               DATE 11/18/80
ENGINE  9.6 L(586. CID) L-6                      TIME 10:03                           DIESEL   EM-465-F
CVS NO.  10                                       DYNO NO.  5                          BAG CART NO.  1

BAROMETER 752.09 MM HG(29.61 IN HG)              RELATIVE HUMIDITY ,  ENGINE-44. PCT ,  CVS-20. PCT
DRY BULB TEMP. 20.0 DEG C(68.0 DEG F)            ABSOLUTE HUMIDITY  6.4 GM/KG( 45.1 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                         1                  2                  3                  4
  DESCRIPTION                                      NYNF               LANF                LAF               NYNF
  BLOWER DIF P MM. H2O(IN. H2O)               685.8 (27.0)       685.8 (27.0)       685.8 (27.0)       685.8 (27.0)
  BLOWER INLET P MM. H2O(IN. H2O)             530.9 (20.9)       530.9 (20.9)       530.9 (20.9)       530.9 (20.9)
  BLOWER INLET TEMP. DEG. C(DEG. F)            48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                            6182.              6265.              6371.              6203.
  TIME SECONDS                                  296.0              300.0              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)             301.0 (10631.)     305.0 (10774.)     310.2 (10956.)     302.0 (10668.)

  HC   SAMPLE METER/RANGE/PPM                  5.2/22/  26.       7.5/22/  38.      13.5/22/  67.       5.6/22/  28.
  HC   BCKGRD METER/RANGE/PPM                  9.4/ 1/   9.       9.0/ 1/   9.       8.6/ 1/   9.       8.1/ 1/   8.
  CO   SAMPLE METER/RANGE/PPM                 75.3/13/  74.      66.7/13/  65.      65.0/13/  63.      64.0/13/  62.
  CO   BCKGRD METER/RANGE/PPM                   .7/13/   1.        .6/13/   1.        .5/13/   0.        .4/13/   0.
  CO2  SAMPLE METER/RANGE/PCT                 16.1/ 3/  .26      22.8/ 3/  .37      54.7/ 3/  .96      15.4/ 3/  .24
  CO2  BCKGRD METER/RANGE/PCT                  3.0/ 3/  .05       2.7/ 3/  .04       2.6/ 3/  .04       2.6/ 3/  .04
  NOX  SAMPLE METER/RANGE/PPM                  6.9/13/  21.       7.8/13/  23.      21.1/13/  63.       7.4/13/  22.
  NOX  BCKGRD METER/RANGE/PPM                   .4/ 2/   0.        .4/ 2/   0.        .4/ 2/   0.        .4/ 2/   0.

  DILUTION FACTOR                              50.38              35.30              13.80              52.89
  HC   CONCENTRATION PPM                       17                 29.                59.                20.
  CO   CONCENTRATION PPM                       72.                63.                61.                61.
  CO2  CONCENTRATION PCT                        .21                .33                .92                .21
  NOX  CONCENTRATION PPM                       20.2               23.1               62.8               21.9

  HC   MASS GRAMS                               2.88               5.09              10.61               3.47
  CO   MASS GRAMS                              25.41              22.44              21.96              21.33
  CO2  MASS GRAMS                            1163.6             1840.2             5235.4             1136.5
  NOX  MASS GRAMS                              11.62              13.47              37.27              12.63
  FUEL KG (LB)                                  .671 (    1.48)   1.083 (    2.39)   3.218 (    7.09)    .627 (    1.38)
  KW HR (HP HR)                                1.07 (    1.44)    1.83 (    2.45)    6.40 (    8.59)    1.08 (    1.45)

  BSHC  G/KW HR (G/HP HR)                      2.68 (    2.00)    2.78 (    2.07)    1.66 (    1.24)    3.21 (    2.39)
  BSCO  G/KW HR (G/HP HR)                     23.68 (   17.66)   12.26 (    9.14)    3.43 (    2.56)   19.72 (   14.70)
  BSCO2 G/KW HR (G/HP HR)                   1084.43 (  808.66) 1005.33 (  749.67)  817.77 (  609.81) 1050.35 (  783.25)
  BSNOX G/KW HR (G/HP HR)                     10.83 (    8.08)    7.36 (    5.49)    5.82 (    4.34)   11.67 (    8.70)
  BSFC  KG/KW HR (LB/HP HR)                    .625 (   1.027)    .591 (    .972)    .503 (    .826)    .580 (    .953)

TOTAL TEST RESULTS 4 BAGS                             PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)           10.39 ( 13.93)           90MM FILTER
   BSHC    G/KW HR (G/HP HR)     2.12 (  1.58)              SAMPLE FLOW      SCM(SCF)                    1.325 ( 46.80)
   BSCO    G/KW HR (G/HP HR)     8.77 (  6.54)              MULTIPLIER FOR   G/TEST                       .919
   BSCO2   G/KW HR (G/HP HR)     903. (  673.)              MULTIPLIER FOR   G/KW HR (G/HP HR)            .0805 ( .0660)
   BSNOX   G/KW HR (G/HP HR)     7.22 (  5.38)              MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)        .1642 ( .0745)
   BSFC   KG/KW HR (LB/HP HR)    .539 (  .886)
                                                         20 X 20 FILTERS
  PART. G/KW-HR (G/HP-HR) .39 (.29)                         SAMPLE FLOW      SCM(SCF)                    83.68 (2955.5)
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TABLE C-15. ENGINE EMISSION RESULTS

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                                     H TRANS.                                 PROJECT NO. 11-5044-001

ENGINE  NO.20                         TEST NO.20-2H  RUN
ENGINE  MODEL   80 VOLVO DUALFUEL     DATE 11/18/80
ENGINE  9.6 L(586. CID) L-6           TIME                         DIESEL   EM-465-F
CVS NO.  10                            DYNO NO.  5                   BAG CART NO.  1

BAROMETER 751.84 MM HG(29.60 IN HG)   RELATIVE HUMIDITY ,  ENGINE-48. PCT ,  CVS-20. PCT
DRY BULB TEMP. 20.6 DEG C(69.0 DEG F) ABSOLUTE HUMIDITY  7.3 GM/KG( 51.0 GRAINS/LB)       NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                 1                    2                    3                    4
   DESCRIPTION                              NYNF                 LANF                  LAF                 NYNF
   BLOWER DIF P MM. H2O(IN. H2O)        685.8 (27.0)         685.8 (27.0)         685.8 (27.0)         685.8 (27.0)
   BLOWER INLET P MM. H2O(IN. H2O)      528.3 (20.8)         528.3 (20.8)         528.3 (20.8)         528.3 (20.8)
   BLOWER INLET TEMP. DEG. C(DEG. F)     48.9 (120.0)         48.9 (120.0)         48.9 (120.0)         48.9 (120.0)
   BLOWER REVOLUTIONS                       6182.                6263.                6371.                6200.
   TIME SECONDS                            276.0                277.9                305.0                276.9
   TOTAL FLOW STD. CU. METRES(SCF)      301.0 (10630.)       304.9 (10769.)       310.2 (10955.)       301.8 (10661.)

   HC  SAMPLE METER/RANGE/PPM            5.7/22/  28.         7.3/22/  37.        13.6/22/  68.         5.4/22/  27.
   HC  BCKGRD METER/RANGE/PPM            6.3/ 1/   6.         6.8/ 1/   7.         7.4/ 1/   7.         7.0/ 1/   7.
   CO  SAMPLE METER/RANGE/PPM           72.9/13/  71.        71.9/13/  70.        78.8/13/  78.        71.8/13/  70.
   CO  BCKGRD METER/RANGE/PPM             .9/13/   1.         5.2/13/   5.        18.8/13/  17.        13.2/13/  12.
   CO2 SAMPLE METER/RANGE/PCT           15.4/ 3/  .24        22.7/ 3/  .37        55.4/ 3/  .97        16.3/ 3/  .26
   CO2 BCKGRD METER/RANGE/PCT            2.9/ 3/  .04         3.1/ 3/  .05         3.1/ 3/  .05         3.3/ 3/  .05
   NOX SAMPLE METER/RANGE/PPM            6.6/13/  20.         7.7/13/  23.        20.1/13/  60.         7.5/13/  22.
   NOX BCKGRD METER/RANGE/PPM             .5/ 2/   1.          .4/ 2/   0.          .6/ 2/   1.          .5/ 2/   1.

   DILUTION FACTOR                          52.68                35.41                13.58                49.30
   HC  CONCENTRATION PPM                    22.                  30.                  61.                  20.
   CO  CONCENTRATION PPM                    70.                  65.                  60.                  58.
   CO2 CONCENTRATION PCT                    .20                  .32                  .93                  .21
   NOX CONCENTRATION PPM                   19.4                 22.8                 59.8                 21.9

   HC  MASS GRAMS                           3.87                 5.30                10.98                 3.53
   CO  MASS GRAMS                          24.43                22.98                21.72                20.27
   CO2 MASS GRAMS                         1107.5               1796.2               5272.1               1160.2
   NOX MASS GRAMS                          11.14                13.30                35.47                12.65
   FUEL KG (LB)                         .640 (    1.41)     1.058 (    2.33)     3.241 (    7.15)      .639 (    1.41)
   KW HR (HP HR)                        1.06 (    1.43)      1.84 (    2.47)      6.37 (    8.54)      1.03 (    1.38)

   BSHC G/KW HR (G/HP HR)               3.63 (    2.71)      2.88 (    2.15)      1.72 (    1.29)      3.44 (    2.56)
   BSCO G/KW HR (G/HP HR)              22.96 (   17.12)     12.50 (    9.32)      3.41 (    2.54)     19.72 (   14.70)
   BSCO2 G/KW HR (G/HP HR)           1040.88 (  776.19)    976.40 (  728.16)    828.17 (  617.57)   1128.65 (  841.63)
   BSNOX G/KW HR (G/HP HR)             10.47 (    7.81)      7.23 (    5.39)      5.57 (    4.15)     12.31 (    9.18)
   BSFC KG/KW HR (LB/HP HR)             .602 (    .990)      .575 (    .946)      .509 (    .837)      .622 (   1.022)

TOTAL TEST RESULTS 4 BAGS                    PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          10.30 ( 13.81)     90MM FILTER
   BSHC    G/KW HR (G/HP HR)    2.30 (  1.71)        SAMPLE FLOW       SCM(SCF)                  1.324 ( 46.78)
   BSCO    G/KW HR (G/HP HR)    8.68 (  6.47)        MULTIPLIER FOR  G/TEST                       .920
   BSCO2   G/KW HR (G/HP HR)    707. (  676.)        MULTIPLIER FOR  G/KW HR (G/HP HR)            .0873 ( .0666)
   BSNOX   G/KW HR (G/HP HR)    7.05 (  5.26)        MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)        .1648 ( .0748)
   BSFC   KG/KW HR (LB/HP HR)   .542 (  .891)
                                                  20 X 20 FILTERS
 PART. G/KW-HR (G/HP-HR)  .39 (.29)                  SAMPLE FLOW      SCM(SCF)                  83.59 (2952.5)
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TABLE C-16.   ENGINE EMISSION RESULTS
                         HOT TRANSIENT2                                    PROJECT NO. 11-5044-001

ENGINE   NO.D20                                  TEST NO.20-1   RUN 2
ENGINE   MODEL    80 VOLVO DUAL FUEL             DATE  9/22/80
ENGINE   9.6 L(586. CID) I-6                     TIME 12:53                          DIESEL   EM-465-F
CVS NO.   10                                      DYNO NO.  5                         BAG CART NO.  1

BAROMETER 740.66 MM HG(29.16 IN HG)              RELATIVE HUMIDITY ,  ENGINE-53. PCT ,  CVS-54. PCT
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)            ABSOLUTE HUMIDITY 10.1 GM/KG( 70.4 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                         1                  2                  3
  BLOWER DIF P MM. H2O(IN. H2O)                647.7 (25.5)       647.7 (25.5)       647.7 (25.5)
  BLOWER INLET P MM. H2O(IN. H2O)              523.2 (20.6)       523.2 (20.6)       523.2 (20.6)
  BLOWER INLET TEMP. DEG. C(DEG. F)             48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                             5694.              6005.              5695.
  TIME SECONDS                                   272.3              287.6              272.8
  TOTAL FLOW STD. CU. METRES(SCF)              272.7 ( 9632.)     287.6 (10158.)     272.8 ( 9634.)

  HC   SAMPLE METER/RANGE/PPM                   6.7/22/  33.       6.8/22/  34.       6.2/22/  31.
  HC   BCKGRD METER/RANGE/PPM                   9.7/ 1/  10.       8.7/ 1/   9.       8.9/ 1/   9.
  CO   SAMPLE METER/RANGE/PPM                  64.1/12/ 143.      74.8/12/ 173.      56.9/12/ 123.
  CO   BCKGRD METER/RANGE/PPM                   .2/12/   0.        .1/12/   0.        .1/12/   0.
  CO2  SAMPLE METER/RANGE/PCT                  21.0/ 3/  .34      26.8/ 3/  .44      21.4/ 3/  .35
  CO2  BCKGRD METER/RANGE/PCT                   2.4/ 3/  .04       2.1/ 3/  .03       2.3/ 3/  .04
  NOX  SAMPLE METER/RANGE/PPM                   9.9/13/  30.      12.8/13/  38.      10.7/13/  32.
  NOX  BCKGRD METER/RANGE/PPM                    .6/ 2/   1.        .9/ 2/   1.        .3/ 2/   0.

  DILUTION FACTOR                                37.65              29.17              37.15
  HC   CONCENTRATION PPM                         24.                25.                22.
  CO   CONCENTRATION PPM                        139.               169.               120.
  CO2  CONCENTRATION PCT                          .30                .41                .31
  NOX  CONCENTRATION PPM                         29.2               37.6               31.9

  HC   MASS GRAMS                                 3.76               4.21               3.54
  CO   MASS GRAMS                                44.10              56.47              38.19
  CO2  MASS GRAMS                              1513.1             2149.5             1555.0
  NOX  MASS GRAMS                                15.25              20.68              16.62
  FUEL KG (LB)                                   .868 (   1.91)    1.295 (   2.86)     .883 (   1.95)
  KW HR (HP HR)                                  1.57 (   2.10)     2.39 (   3.21)     1.60 (   2.15)

  BSHC  G/KW HR (G/HP HR)                        2.40 (   1.79)     1.76 (   1.31)     2.21 (   1.65)
  BSCO  G/KW HR (G/HP HR)                       28.15 (  20.99)    23.63 (  17.62)    23.84 (  17.78)
  BSCO2 G/KW HR (G/HP HR)                      965.69 ( 720.12)   899.36 ( 670.65)   970.55 ( 723.74)
  BSNOX G/KW HR (G/HP HR)                        9.74 (   7.26)     8.65 (   5.45)    10.37 (   7.74)
  BSFC  KG/KW HR (LB/HP HR)                      .554 (   .911)     .542 (   .891)     .551 (   .906)

TOTAL TEST RESULTS 3 BAGS                             PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)          5.56 (  7.45)              90MM FILTER
  BSHC    G/KW HR (G/HP HR)    2.07 (  1.54)                 SAMPLE FLOW      SCM(SCF)                   .735 ( 25.96)
  BSCO    G/KW HR (G/HP HR)   24.96 ( 18.61)                 MULTIPLIER FOR   G/TEST                    1.133
  BSCO2   G/KW HR (G/HP HR)   939.  (  700.)                 MULTIPLIER FOR   G/KW HR (G/HP HR)          .2039 ( .1520)
  BSNOX   G/KW HR (G/HP HR)    9.45 (  7.05)                 MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)      .3720 ( .1687)
  BSFC   KG/KW HR (LB/HP HR)   .548 (  .901)
                                                           20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)   .64 (.48)                          SAMPLE FLOW      SCM(SCF)                 55.63 (1965.0)
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TABLE C-17.

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. ENGINE EMISSION RESULTS
                    HOT TRANSIENTS                                                  PROJECT NO. 11-5044-001

ENGINE   NO.D20                                   TEST NO.20-1    RUN 3
ENGINE   MODEL    80 VOLVO DUAL FUEL              DATF  9/22/80
ENGINE   9.6 L(586. CID) I-6                      TIME  1:29                         DIESEL    EM-465-F
CVS NO.  10                                        DYNO NO.  5                       BAG CART NO.  1

BAROMETER 740.66 MM HG(29.16 IN HG)               RELATIVE HUMIDITY ,  ENGINE-52. PCT ,  CVS-54. PCT
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)             ABSOLUTE HUMIDITY 10.2 GM/KG( 71.4 GRAINS/LD)       NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                       1                    2                    3
  BLOWER DIF P MM. H2O(IN. H2O)              647.7 (25.5)         647.7 (25.5)         647.7 (25.5)
  BLOWER INLET P MM. H2O(IN. H2O)            523.2 (20.6)         523.2 (20.6)         523.2 (20.6)
  BLOWER INLET TEMP. DEG. C(DEG. F)           48.9 (120.0)         48.9 (120.0)         48.9 (120.0)
  BLOWER REVOLUTIONS                           5696.                6005.                5695.
  TIME SECONDS                                 272.8                287.7                272.7
  TOTAL FLOW STD. CU. METRES(SCF)            272.8 ( 9635.)       287.6 (10158.)       272.7 ( 9633.)

   HC  SAMPLE METER/RANGE/PPM                 6.7/22/  33.         6.9/22/  34.         6.3/22/  31.
   HC  BCKGRD METER/RANGE/PPM                 9.7/ 1/  10.         9.0/ 1/   9.         8.2/ 1/   8.
   CO  SAMPLE METER/RANGE/PPM                61.9/12/ 137.        74.3/12/ 172.        58.2/12/ 127.
   CO  BCKGRD METER/RANGE/PPM                  .1/12/   0.          .1/12/   0.          .1/12/   0.
   CO2 SAMPLE METER/RANGE/PCT                21.3/ 3/  .34        27.3/ 3/  .45        21.7/ 3/  .35
   CO2 BCKGRD METER/RANGE/PCT                 2.5/ 3/  .04         2.1/ 3/  .03         2.2/ 3/  .03
   NOX SAMPLE METER/RANGE/PPM                 8.0/13/  24.        10.2/13/  30.         8.7/13/  26.
   NOX BCKGRD METER/RANGE/PPM                  .5/ 2/   1.          .5/ 2/   1.          .5/ 2/   1.

   DILUTION FACTOR                             37.18                28.63                36.60
   HC  CONCENTRATION PPM                       24.                  26.                  23.
   CO  CONCENTRATION PPM                       133.                 167.                 124.
   CO2 CONCENTRATION PCT                        .31                  .42                  .32
   NOX CONCENTRATION PPM                       23.6                 30.0                 25.5

   HC   MASS GRAMS                              3.75                 4.25                 3.69
   CO   MASS GRAMS                             42.31                55.97                39.24
   CO2  MASS GRAMS                            1531.7               2195.8               1588.1
   NOX  MASS GRAMS                             12.31                16.50                13.30
   FUEL KG (LB)                                .877 (    1.93)     1.318 (    2.91)      .974 (    2.15)
   KW HR (HP HR)                               1.57 (    2.10)      2.37 (    3.18)      1.58 (    2.11)

   BSHC G/KW HR (G/HP HR)                      2.39 (    1.78)      1.79 (    1.33)      2.34 (    1.75)
   BSCO G/KW HR (G/HP HR)                     27.00 (   20.14)     23.59 (   17.59)     24.90 (   18.57)
   BSCO2 G/KW HR (G/HP HR)                   977.59 ( 728.99)    925.57 ( 690.19)   1007.89 ( 751.59)
   BSNOX G/KW HR (G/HP HR)                     7.85 (    5.86)      6.96 (    5.19)      8.44 (    6.29)
   BSFC KG/KW HR (LB/HP HR)                    .560 (    .920)      .555 (    .913)      .618 (   1.017)

TOTAL TEST RESULTS 3 BAGS                               PARTICULATE DATA, TOTAL FOR 3 BAGS

   TOTAL KW HR (HP HR)          5.51 (   7.40)              90MM FILTER
   BSHC    G/KW HR (G/HP HR)    2.12 (   1.58)                  SAMPLE FLOW        SCM(SCF)                  .737 ( 26.03)
   BSCO    G/KW HR (G/HP HR)   24.94 (  18.59)                  MULTIPLIER FOR     G/TEST                    1.130
   BSCO2   G/KW HR (G/HP HR)    964. (   719.)                  MULTIPLIER FOR     G/KW HR (G/HP HR)         .2050 ( .1528)
   BSNOX   G/KW HR (G/HP HR)    7.64 (   5.69)                  MULTIPLIER FOR     G/KG FUEL (G/LB FUEL)     .3567 ( .1618)
   BSFC   KG/KW HR (LB/HP HR)   .575 (   .945)
                                                             20 X 20 FILTERS
                                                                SAMPLE FLOW      SCM(SCF)                    55.58 (1963.1)
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PART. G/KW-HR (G/HP-HR) .63 (.47)

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                                   TABLE C-18.  ENGINE EMISSION RESULTS
                                                    HOT TRANSIENT                                   PROJECT NO. 11-5044-001

ENGINE   NO.D20                                      TEST NO.20-28   RUN 3
ENGINE   MODEL    80 VOLVO DUAL FUEL                 DATE   9/29/80
ENGINE   9.6 L(586. CID) L-6                         TIME                                       DIESEL    EM-465-F
CVS NO.   10                                          DYNO NO.  5                                 BAG CART NO.  1

BAROMETER 739.14 MM HG(29.10 IN HG)                  RELATIVE HUMIDITY ,  ENGINE-42. PCT ,  CVS-60. PCT
DRY BULB TEMP. 28.3 DEG C(83.0 DEG F)                ABSOLUTE HUMIDITY 10.3 GM/KG( 71.8 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                               1                  2                  3
  BLOWER DIF P MM. H2O(IN. H2O)                     660.4 (26.0)       660.4 (26.0)       660.4 (26.0)
  BLOWER INLET P MM. H2O(IN. H2O)                   518.2 (20.4)       518.2 (20.4)       518.2 (20.4)
  BLOWER INLET TEMP. DEG. C(DEG. F)                  48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                                   5694.              6010.              5695.
  TIME SECONDS                                        272.7              287.9              272.8
  TOTAL FLOW STD. CU. METRES(SCF)                   272.0 ( 9606.)     287.1 (10139.)     272.0 ( 9608.)

  HC   SAMPLE METER/RANGE/PPM                        5.9/22/  30.       5.4/22/  27.       5.6/22/  28.
  HC   BCKGRD METER/RANGE/PPM                        9.0/ 1/   9.       9.1/ 1/   9.      10.0/ 1/  10.
  CO   SAMPLE METER/RANGE/PPM                       52.6/12/ 139.      75.3/12/ 175.      57.1/12/ 124.
  CO   BCKGRD METER/RANGE/PPM                         .4/12/   1.        .7/12/   1.       1.8/12/   3.
  CO2  SAMPLE METER/RANGE/PCT                       20.5/ 3/  .33      24.5/ 3/  .40      20.8/ 3/  .34
  CO2  BCKGRD METER/RANGE/PCT                        3.1/ 3/  .05       2.8/ 3/  .04       2.8/ 3/  .04
  NOX  SAMPLE METER/RANGE/PPM                        7.7/13/  23.       9.0/13/  27.       8.5/13/  25.
  NOX  BCKGRD METER/RANGE/PPM                         .7/ 2/   1.        .7/ 2/   1.        .8/ 2/   1.

  DILUTION FACTOR                                     38.66              32.01              38.27
  HC   CONCENTRATION PPM                              21.                18.                19.
  CO   CONCENTRATION PPM                             134.               169.               118.
  CO2  CONCENTRATION PCT                               .28                .36                .29
  NOX  CONCENTRATION PPM                              22.4               26.2               24.7

  HC   MASS GRAMS                                      3.26               3.01               2.90
  CO   MASS GRAMS                                     42.53              56.43              37.23
  CO2  MASS GRAMS                                   1414.1             1379.1             1462.4
  NOX  MASS GRAMS                                     11.68              14.38              12.86
  FUEL KG (LB)                                        .855 (    1.89)   1.249 (    2.75)    .878 (    1.93)
  KW HR (HP HR)                                       1.41 (    1.89)    2.20 (    2.94)    1.41 (    1.89)

  BSHC G/KW HR (G/HP HR)                              2.32 (    1.73)    1.37 (    1.02)    2.06 (    1.54)
  BSCO G/KW HR (G/HP HR)                             30.21 (   22.53)   25.70 (   19.17)   26.45 (   19.72)
  BSCO2 G/KW HR (G/HP HR)                          1004.71 (  749.21)  855.95 (  638.28) 1038.99 (  774.77)
  BSNOX G/KW HR (G/HP HR)                             8.30 (    6.19)    6.55 (    4.88)    9.14 (    6.81)
  BSFC KG/KW HR (LB/HP HR)                            .608 (    .999)    .569 (    .935)    .624 (   1.025)

TOTAL TEST RESULTS 3 BAGS                              PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)           5.01 (   6.72)          90MM FILTER
   BSHC    G/KW HR (G/HP HR)     1.83 (   1.37)              SAMPLE FLOW      SCM(SCF)                 .750 ( 26.50)
   BSCO    G/KW HR (G/HP HR)    27.18 (  20.27)              MULTIPLIER FOR   G/TEST                  1.108
   BSCO2   G/KW HR (G/HP HR)    949.  (  708.)               MULTIPLIER FOR   G/KW HR (G/HP HR)        .2211 ( .1649)
   BSNOX   G/KW HR (G/HP HR)     7.77 (   5.79)              MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)    .3715 ( .1685)
   BSFC   KG/KW HR (LB/HP HR)    .595 (   .978)
                                                        20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .55 (.41)                          SAMPLE FLOW     SCM(SCF)                 55.12 (1946.9)
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TABLE C-19. ENGINE EMISSION RESULTS HOT TRANSIENT

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                                                                                    PROJECT NO. 11-5044-001

ENGINE   NO.D20                          TEST NO.20-1B  RUN
ENGINE   MODEL    80 VOLVO DUAL FUEL     DATE  9/30/80
ENGINE   9.6 L(586. CID) L-6             TIME 11:20                       DIESEL    EM-465-F
CVS NO.   10                              DYNO NO.  5                      BAG CART NO.  1

BAROMETER 741.93 MM HG(29.21 IN HG)      RELATIVE HUMIDITY ,  ENGINE-52. PCT ,  CVS-60. PCT
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)    ABSOLUTE HUMIDITY 10.5 GM/KG( 73.7 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                    1                   2                   3
   BLOWER DIF P MM. H2O(IN. H2O)          670.6 (26.4)        670.6 (26.4)        670.6 (26.4)
   BLOWER INLET P MM. H2O(IN. H2O)        523.2 (20.6)        523.2 (20.6)        523.2 (20.6)
   BLOWER INLET TEMP. DEG. C(DEG. F)       48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
   BLOWER REVOLUTIONS                        5693.               6010.               5693.
   TIME SECONDS                              272.3               287.8               272.6
   TOTAL FLOW STD. CU. METRES(SCF)        272.8 ( 9635.)      288.0 (10171.)      272.8 ( 9635.)

   HC  SAMPLE METER/RANGE/PPM              6.0/22/  30.        5.5/22/  28.        5.5/22/  28.
   HC  BCKGRD METER/RANGE/PPM              9.8/ 1/  10.        9.2/ 1/   9.       10.0/ 1/  10.
   CO  SAMPLE METER/RANGE/PPM             61.6/12/ 136.       72.9/12/ 168.       55.7/12/ 120.
   CO  BCKGRD METER/RANGE/PPM              3.7/12/   7.        3.3/12/   6.        3.5/12/   7.
   CO2 SAMPLE METER/RANGE/PCT             20.6/ 3/  .33       24.4/ 3/  .40       20.4/ 3/  .33
   CO2 BCKGRD METER/RANGE/PCT              3.4/ 3/  .05        3.3/ 3/  .05        3.8/ 3/  .06
   NOX SAMPLE METER/RANGE/PPM              9.3/13/  28.       10.4/13/  31.        9.8/13/  29.
   NOX BCKGRD METER/RANGE/PPM               .9/ 2/   1.         .8/ 2/   1.         .9/ 2/   1.

   DILUTION FACTOR                           38.50               32.19               39.08
   HC   CONCENTRATION PPM                    20.                 19.                 18.
   CO   CONCENTRATION PPM                   126.                157.                111.
   CO2 CONCENTRATION PCT                      .28                 .35                 .27
   NOX CONCENTRATION PPM                     26.9                30.4                28.6

   HC   MASS GRAMS                           3.20                3.09                2.83
   CO   MASS GRAMS                          39.94               52.73               35.24
   CO2 MASS GRAMS                         1404.2              1836.3              1357.0
   NOX MASS GRAMS                          14.03               16.77               14.92
   FUEL KG (LB)                              .844 (    1.86)   1.150 (    2.54)     .789 (    1.74)
   KW HR (HP HR)                            1.43 (    1.92)    2.22 (    2.98)     1.43 (    1.91)

   BSHC G/KW HR (G/HP HR)                   2.23 (    1.66)    1.39 (    1.04)     1.99 (    1.48)
   BSCO G/KW HR (G/HP HR)                  27.85 (   20.77)   23.73 (   17.70)    24.73 (   18.44)
   BSCO2 G/KW HR (G/HP HR)                979.21 (  730.20)  826.46 (  616.29)   952.14 (  710.01)
   BSNOX G/KW HR (G/HP HR)                  9.78 (    7.30)    7.55 (    5.63)    10.47 (    7.81)
   BSFC KG/KW HR (LB/HP HR)                 .589 (    .968)    .518 (    .851)     .554 (    .910)

TOTAL TEST RESULTS 3 BAGS                    PARTICULATE DATA, TOTAL FOR 3 BAGS

   TOTAL KW HR (HP HR)           5.08 (  6.81)     90MM FILTER
   BSHC    G/KW HR (G/HP HR)     1.79 (  1.34)          SAMPLE FLOW      SCM(SCF)                   .764 ( 27.00)
   BSCO    G/KW HR (G/HP HR)    25.17 ( 18.77)          MULTIPLIER FOR   G/TEST                    1.090
   BSCO2   G/KW HR (G/HP HR)   905.   ( 675.)           MULTIPLIER FOR   G/KW HR (G/HP HR)          .2146 ( .1600)
   BSNOX   G/KW HR (G/HP HR)     9.00 (  6.71)          MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)      .3917 ( .1777)
   BSFC    KG/KW HR (LB/HP HR)   .548 (  .901)
                                                    20 X 20 FILTERS
                                                       SAMPLE FLOW     SCM(SCF)                   55.28 (1952.3)

 PART. G/KW-HR (G/HP-HR)  .58 (.43)
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TABLE C-20. ENGINE EMISSION RESULTS

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                                        H-TRANS.                                   PROJECT NO. 11-5044-001

ENGINE  NO.D20                          TEST NO.20-1B  RUN
ENGINE  MODEL   80 VOLVO DUALFUEL       DATE 11/18/80
ENGINE  9.6 L(586. CID) L-6             TIME                              DIESEL   EM-465-F
CVS NO.  10                              DYNO NO.  5                       BAG CART NO.  1

BAROMETER 751.84 MM HG(27.60 IN HG)     RELATIVE HUMIDITY ,  ENGINE-37. PCT ,  CVS-20. PCT
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)   ABSOLUTE HUMIDITY  6.2 GM/KG( 43.5 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                   1                   2                   3
  BLOWER DIF P MM. H2O(IN. H2O)          685.8 (27.0)        685.8 (27.0)        685.8 (27.0)
  BLOWER INLET P MM. H2O(IN. H2O)        528.3 (20.8)        528.3 (20.8)        528.3 (20.8)
  BLOWER INLET TEMP. DEG. C(DEG. F)       48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
  BLOWER REVOLUTIONS                       5694.               6011.               5692.
  TIME SECONDS                             272.6               287.8               272.6
  TOTAL FLOW STD. CU. METRES(SCF)        277.2 ( 9792.)      292.7 (10337.)      277.1 ( 9789.)

  HC  SAMPLE METER/RANGE/PPM              5.5/22/  28.        5.6/22/  28.        5.4/22/  27.
  HC  BCKGRD METER/RANGE/PPM              6.5/ 1/   7.        6.5/ 1/   7.        6.5/ 1/   7.
  CO  SAMPLE METER/RANGE/PPM             91.5/13/  92.       50.0/12/ 106.       83.3/13/  83.
  CO  BCKGRD METER/RANGE/PPM              5.4/13/   5.        1.7/12/   3.        2.5/13/   2.
  CO2 SAMPLE METER/RANGE/PCT             18.4/ 3/  .29       23.0/ 3/  .37       19.4/ 3/  .31
  CO2 BCKGRD METER/RANGE/PCT              2.6/ 3/  .04        2.8/ 3/  .04        3.1/ 3/  .05
  NOX SAMPLE METER/RANGE/PPM              9.5/13/  28.       11.0/13/  33.       10.1/13/  30.
  NOX BCKGRD METER/RANGE/PPM               .4/ 2/   0.         .4/ 2/   0.         .4/ 2/   0.

  DILUTION FACTOR                          43.72               34.70               41.57
  HC  CONCENTRATION PPM                     21.                 22.                 21.
  CO  CONCENTRATION PPM                     86.                101.                 80.
  CO2 CONCENTRATION PCT                     .26                 .33                 .27
  NOX CONCENTRATION PPM                    28.0                32.5                30.0

  HC  MASS GRAMS                           3.42                3.66                3.29
  CO  MASS GRAMS                          27.89               34.56               25.71
  CO2 MASS GRAMS                         1298.5              1776.1              1345.8
  NOX MASS GRAMS                          14.84               18.19               15.92
  FUEL KG (LB)                            .776 (   1.71)     1.164 (   2.57)      .801 (   1.77)
  KW HR (HP HR)                           1.29 (   1.73)     2.06 (   2.76)      1.24 (   1.67)

  BSHC G/KW HR (G/HP HR)                  2.65 (   1.98)     1.78 (   1.33)      2.65 (   1.97)
  BSCO G/KW HR (G/HP HR)                 21.63 (  16.13)    16.81 (  12.54)     20.66 (  15.41)
  BSCO2 G/KW HR (G/HP HR)              1007.05 ( 750.96)   863.92 ( 644.23)   1081.52 ( 806.49)
  BSNOX G/KW HR (G/HP HR)                11.51 (   8.58)     8.85 (   6.60)     12.80 (   9.54)
  BSFC KG/KW HR (LB/HP HR)                .602 (   .989)     .566 (   .931)      .644 (  1.058)

TOTAL TEST RESULTS 3 BAGS                             PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)          4.59 (  6.15)              90MM FILTER
  BSHC   G/KW HR (G/HP HR)     2.26 (  1.69)                SAMPLE FLOW      SCM(SCF)                    .911 ( 32.19)
  BSCO   G/KW HR (G/HP HR)    19.21 ( 14.32)                MULTIPLIER FOR   G/TEST                      .929
  BSCO2  G/KW HR (G/HP HR)    963.  ( 718.)                 MULTIPLIER FOR   G/KW HR (G/HP HR)           .2025 ( .1510)
  BSNOX  G/KW HR (G/HP HR)    10.66 (  7.95)                MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)       .3391 ( .1530)
  BSFC  KG/KW HR (LB/HP HR)    .597 (  .982)
                                                          20 X 20 FILTERS
 PART. G/KW-HR (G/HP-HR)  .60 (.45)                          SAMPLE FLOW      SCM(SCF)                   58.25 (2057.4)
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APPENDIX D

TRANSIENT TEST RESULTS FROM THE METHANOL-CATALYST CONFIGURATION

TABLE D-1. NOTES CONCERNING TEST RESULTS GIVEN IN APPENDIX D

Table No.	Notes
Methanol & Catalyst	
Cold Start	
D-2	Passed statistical requirements. Results used for regulated emissions. NO_x by bag measurement was 7.12 g/kW-hr.
D-3	Failed statistical requirements TQ intercept - 18.6. Results used for regulated emissions. NO_x by bag measurement was 7.43 g/kW-hr.
D-4	Volvo requested that throttle be fully closed during idle to insure electrical contact for solenoid operation. In order to assure throttle closure large negative torque command was generated by the control tape. With the throttle fully closed the engine may have been motored more than for previous runs. Results from these tests were not used for regulated emissions. Failed statistical requirements, TQ intercept -18.8, torque and power slope about 4% high. Further runs for record with negative TQ command were discontinued and other methods of dynamometer control were pursued.
Hot Start	
D-5	Failed statistical requirements, TQ intercept -16.4. Results used for regulated emissions.
D-6	Passed statistical requirements. Results used for regulated emissions.
D-7	Same as D-4 but test passed statistical requirements. Results not used for regulated emissions.
Bus Cycle	
D-8	Failed statistical requirements, TQ intercept -16.8. Results used for regulated emissions. NO_x by bag measurement was 7.76 g/kW-hr.
D-9	Failed statistical requirements, TQ R^2 3 percent low. Results used for regulated emissions. NO_x by bag measurement was 7.81 g/kW-hr. NO_x emission estimated to be 8.03 g/kW-hr on the basis of bag NO_x.

TABLE D-1 (CONT'D). NOTES CONCERNING TEST RESULTS GIVEN IN APPENDIX D

Table No.	Notes
Methanol & Catalyst & Back Pressure Device	
Cold Start	
D-10	Volvo requested that a backpressure device be used in conjunction with the catalyst. The device is only effective at closed throttle conditions such as motoring and at idle and serves as a "fast engine and catalyst warm-up device." Idle diesel fuel rate was increased to maintain curb idle speed. Results used for regulated emission. Failed statistical requirements, torque, and power slope about 2 percent high, torque and power intercept - 29.5 and -5.3 respectively. NO_x measurement was 8.18 g/kW-hr.
D-11	Failed statistical requirements, TQ intercept - 24.8%. Cycle power >15 percent below cycle command power. Results used for regulated emissions. NO_x by bag measurement was 8.47 g/kW-hr.
Hot Start	
D-12	Failed statistical requirements, TQ and Power intercept were -32.9 and -6.6, torque and power slope were ∿6 percent high. Results used for regulated emissions.
D-13	Failed statistical requirements, TQ and power slope were 1 percent and 4 percent high, respectively. Results used for regulated emissions.
Bus Cycle	
D-14	Failed statistical requirements, TQ R^2 slightly low. Results used for regulated emissions.

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                         TABLE D-2.   ENGINE EMISSION RESULTS
                                           COLD TRANSIENT                                    PROJECT NO. 11-5044-001

ENGINE   NO.D20                                       TEST NO.21-1C   RUN
ENGINE   MODEL   80 VOLVO DUAL FUEL                   DATE 10/ 3/80
ENGINE   9.6 L(586. CID) L-6                          TIME                                 DIESEL    EM-465-F
CVS NO.  10                                             DYNO NO.  5                          BAG CART NO.  1

BAROMETER 747.27 MM HG(29.42 IN HG)                   RELATIVE HUMIDITY ,  ENGINE-49. PCT ,  CVS-61. PCT
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)                 ABSOLUTE HUMIDITY 10.2 GM/KG( 71.2 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                          1                  2                   3                   4
   DESCRIPTION                                        NYNF               LANF                LAF                 NYNF
   BLOWER DIF P MM. H2O(IN. H2O)                  670.6 (26.4)       670.6 (26.4)        670.6 (26.4)        670.6 (26.4)
   BLOWER INLET P MM. H2O(IN. H2O)                520.7 (20.5)       520.7 (20.5)        520.7 (20.5)        520.7 (20.5)
   BLOWER INLET TEMP. DEG. C(DEG. F)               48.9 (120.0)       48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
   BLOWER REVOLUTIONS                                6182.              6262.               6371.               6201.
   TIME SECONDS                                     296.0              299.9               305.0               297.0
   TOTAL FLOW STD. CU. METRES(SCF)                299.1 (10563.)     303.0 (10700.)      308.2 (10886.)      300.0 (10596.)

   HC   SAMPLE METER/RANGE/PPM                     4.3/22/  22.       2.9/22/  15.        1.8/22/   9.        1.5/22/   7.
   HC   BCKGRD METER/RANGE/PPM                     9.4/ 1/   9.       8.9/ 1/   9.        7.6/ 1/   8.        8.7/ 1/   9.
   CO   SAMPLE METER/RANGE/PPM                    57.2/12/ 124.      50.8/13/  48.       13.3/13/  12.       16.8/13/  15.
   CO   BCKGRD METER/RANGE/PPM                     3.5/12/   7.       7.2/13/   6.        7.6/13/   7.        6.3/13/   5.
   CO2  SAMPLE METER/RANGE/PCT                    19.0/ 3/  .30      25.7/ 3/  .42       57.0/ 3/ 1.00       16.5/ 3/  .26
   CO2  BCKGRD METER/RANGE/PCT                     3.2/ 3/  .05       3.2/ 3/  .05        3.1/ 3/  .05        3.0/ 3/  .05
   NOX  SAMPLE METER/RANGE/PPM                     7.8/13/  23.       9.1/13/  27.       25.4/13/  76.        7.8/13/  23.
   NOX  BCKGRD METER/RANGE/PPM                     1.0/ 2/   1.        .9/ 2/   1.         .8/ 2/   1.         .8/ 2/   1.

   DILUTION FACTOR                                  42.01              31.46               13.32               50.58
   HC   CONCENTRATION PPM                           12.                 6.                  2.                 -1.
   CO   CONCENTRATION PPM                          115.                41.                  5.                  9.
   CO2  CONCENTRATION PCT                            .26                .37                 .96                 .22
   NOX  CONCENTRATION PPM                           22.5               26.5                75.3                22.5

   HC   MASS GRAMS                                   2.15               1.05                 .39                -.22
   CO   MASS GRAMS                                  39.96              14.35                1.88                3.22
   CO2  MASS GRAMS                                1406.9             2065.9              5417.1              1196.3
   NOX  MASS GRAMS                                  12.88              15.36               44.41               12.91
   FUEL KG (LB)                                     .810 (   1.79)    1.208 (   2.66)     3.314 (   7.31)      .636 (   1.40)
   KW HR (HP HR)                                    1.12 (   1.51)    2.01 (   2.69)      6.85 (   9.19)      1.10 (   1.47)

   BSHC G/KW HR (G/HP HR)                           1.91 (   1.43)     .52 (    .39)       .06 (    .04)      -.20 (   -.15)
   BSCO G/KW HR (G/HP HR)                          35.55 (  26.51)    7.14 (   5.32)       .27 (    .20)      2.93 (   2.19)
   BSCO2 G/KW HR (G/HP HR)                       1251.46 ( 933.22) 1028.09 ( 766.65)   790.64 ( 589.58)  1089.87 ( 812.72)
   BSNOX G/KW HR (G/HP HR)                         11.46 (   8.55)    7.64 (   5.70)      6.48 (   4.83)     11.76 (   8.77)
   BSFC KG/KW HR (LB/HP HR)                         .720 (  1.184)    .601 (   .988)      .484 (   .795)      .579 (   .953)
TOTAL TEST RESULTS 4 BAGS                                PARTICULATE DATA, TOTAL FOR 4 BAGS

   TOTAL KW HR (HP HR)        11.08 ( 14.86)                90MM FILTER
   BSHC    G/KW HR (G/HP HR)    .30 (   .23)                    SAMPLE FLOW      SCM(SCF)                 1.279 ( 45.18)
   BSCO    G/KW HR (G/HP HR)   5.36 (  4.00)                    MULTIPLIER FOR   G/TEST                    .946
   BSCO2   G/KW HR (G/HP HR)   910. (  679.)                    MULTIPLIER FOR   G/KW HR (G/HP HR)         .0854 ( .0637)
   BSNOX   G/KW HR (G/HP HR)   7.72 (  5.76)                    MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)     .1585 ( .0719)
   BSFC   KG/KW HR (LB/HP HR)  .538 (  .885)
                                                            20 X 20 FILTERS
                                                                 SAMPLE FLOW      SCM(SCF)                81.88 (2892.0)

PART. G/KW-HR (G/HP-HR)  .25 (.19)
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TABLE D-3. ENGINE EMISSION RESULTS COLD TRANSIENT

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                                                                                         PROJECT NO. 11-5044-001

ENGINE  NO.D20                                 TEST NO.21-2C  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL             DATE 10/ 7/80
ENGINE  9.6 L(586. CID) L-6                    TIME                             DIESEL   EM-465-F
CVS NO.  10                                      DYNO NO.  5                      BAG CART NO.  1

BAROMETER 747.78 MM HG(29.44 IN HG)            RELATIVE HUMIDITY ,  ENGINE-51. PCT ,  CVS-47. PCT
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)          ABSOLUTE HUMIDITY 10.2 GM/KG( 71.7 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                        1                    2.                    3                    4
   DESCRIPTION                                     NYNF                 LANF                  LAF                 NYNF
   BLOWER DIF P MM. H2O(IN. H2O)              670.6 (26.4)         670.6 (26.4)         670.6 (26.4)         670.6 (26.4)
   BLOWER INLET P MM. H2O(IN. H2O)            520.7 (20.5)         520.7 (20.5)         520.7 (20.5)         520.7 (20.5)
   BLOWER INLET TEMP. DEG. C(DEG. F)           48.9 (120.0)         48.9 (120.0)         48.9 (120.0)         48.9 (120.0)
   BLOWER REVOLUTIONS                            6181.                6264.                6370.                6202.
   TIME SECONDS                                  296.0                300.0                305.0                297.0
   TOTAL FLOW STD. CU. METRES(SCF)            299.5 (10577.)       303.5 (10719.)       308.6 (10900.)       300.5 (10613.)

   HC  SAMPLE METER/RANGE/PPM                 23.3/11/  23.        16.3/11/  16.        11.1/11/  11.         9.2/11/   9.
   HC  BCKGRD METER/RANGE/PPM                  9.8/ 1/  10.         9.2/ 1/   9.         7.6/ 1/   8.         8.3/ 1/   8.
   CO  SAMPLE METER/RANGE/PPM                 54.0/12/ 116.        52.7/13/  50.         9.7/13/   8.        18.5/13/  16.
   CO  BCKGRD METER/RANGE/PPM                   .6/12/   1.         1.5/13/   1.         1.4/13/   1.         1.5/13/   1.
   CO2 SAMPLE METER/RANGE/PCT                 18.8/ 3/  .30        25.2/ 3/  .41        57.0/ 3/ 1.00        16.8/ 3/  .27
   CO2 BCKGRD METER/RANGE/PCT                  2.7/ 3/  .04         2.6/ 3/  .04         2.7/ 3/  .04         2.7/ 3/  .04
   NOX SAMPLE METER/RANGE/PPM                  6.6/13/  20.         7.9/13/  24.        23.9/13/  72.         8.3/13/  25.
   NOX BCKGRD METER/RANGE/PPM                   .7/ 2/   1.          .8/ 2/   1.         1.0/ 2/   1.          .8/ 2/   1.

   DILUTION FACTOR                                42.54                32.09                13.33                49.58
   HC  CONCENTRATION PPM                          14.                   7.                   4.                   1.
   CO  CONCENTRATION PPM                         112.                  48.                   7.                  15.
   CO2 CONCENTRATION PCT                          .26                  .37                  .97                  .23
   NOX CONCENTRATION PPM                          19.2                 22.8                 70.7                 24.2

   HC  MASS GRAMS                                 2.37                 1.29                  .72                  .19
   CO  MASS GRAMS                                39.21                16.81                 2.55                 5.18
   CO2 MASS GRAMS                               1431.4               2070.7               5456.2               1250.8
   NOX MASS GRAMS                                10.98                13.26                41.76                13.93
   FUEL KG (LB)                                .754 (   1.66)     1.215 (   2.68)     3.346 (   7.38)      .686 (   1.51)
   KW HR (HP HR)                               1.12 (   1.50)      2.02 (   2.71)      6.86 (   9.20)      1.17 (   1.57)

   BSHC G/KW HR (G/HP HR)                      2.13 (   1.59)       .64 (    .48)       .11 (    .08)       .16 (    .12)
   BSCO G/KW HR (G/HP HR)                     35.15 (  26.21)      8.33 (   6.21)       .37 (    .28)      4.44 (   3.31)
   BSCO2 G/KW HR (G/HP HR)                  1283.38 ( 957.01)   1025.97 ( 765.07)    795.33 ( 593.08)   1070.45 ( 798.24)
   BSNOX G/KW HR (G/HP HR)                     9.84 (   7.34)      6.57 (   4.90)      6.09 (   4.54)     11.92 (   8.89)
   BSFC KG/KW HR (LB/HP HR)                    .676 (  1.111)      .602 (   .990)      .488 (   .802)      .587 (   .966)

TOTAL TEST RESULTS 4 BAGS                               PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)            11.16 ( 14.97)             90MM FILTER
   BSHC    G/KW HR (G/HP HR)       .41 (   .31)                 SAMPLE FLOW      SCM(SCF)                 1.243 ( 43.92)
   BSCO    G/KW HR (G/HP HR)      5.71 (  4.26)                 MULTIPLIER FOR  G/TEST                    .975
   BSCO2   G/KW HR (G/HP HR)      915. (  682.)                 MULTIPLIER FOR  G/KW HR (G/HP HR)         .0873 ( .0651)
   BSNOX   G/KW HR (G/HP HR)      7.16 (  5.34)                 MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)     .1624 ( .0737)
   BSFC    KG/KW HR (LB/HP HR)    .538 (  .884)
                                                            20 X 20 FILTERS
                                                                SAMPLE FLOW      SCM(SCF)                 82.82 (2925.1)
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PART. G/KW-HR (G/HP-HR) .25 (.19)

NEGATIVE TORQUE COMMAND

TABLE D-4. ENGINE EMISSION RESULTS

COLD TRANSIENT

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                                                                                      PROJECT NO. 11-5044-001
ENGINE  NO.D20                                     TEST NO.21-4C  RUN
ENGINE  MODEL    80 VOLVO DUAL FUEL                DATE 10/ 9/80
ENGINE  9.6 L(586. CID) L-6                        TIME                              DIESEL   EM-465-F
CVS NO.  10                                         DYNO NO.  5                        BAG CART NO.  1

BAROMETER 739.90 MM HG(29.13 IN HG)                RELATIVE HUMIDITY ,  ENGINE-46. PCT ,  CVS- 0. PCT
DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)              ABSOLUTE HUMIDITY 10.2 GM/KG( 71.3 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                        1                    2                    3                    4
  DESCRIPTION                                      NYNF                 LANF                 LAF                  NYNF
  BLOWER DIF P MM. H2O(IN. H2O)               670.6 (26.4)        670.6 (26.4)        670.6 (26.4)        670.6 (26.4)
  BLOWER INLET P MM. H2O(IN. H2O)             520.7 (20.5)        520.7 (20.5)        520.7 (20.5)        520.7 (20.5)
  BLOWER INLET TEMP. DEG. C(DEG. F)            48.9 (120.0)        48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
  BLOWER REVOLUTIONS                              6205.               6267.               6372.               6204.
  TIME SECONDS                                    297.0               300.0               305.0               297.0
  TOTAL FLOW STD. CU. METRES(SCF)             296.7 (10481.)      299.7 (10586.)      304.7 (10763.)      296.7 (10479.)

  HC   SAMPLE METER/RANGE/PPM                 28.9/ 2/  29.       23.8/ 2/  24.       20.9/ 2/  21.       16.8/ 2/  17.
  HC   BCKGRD METER/RANGE/PPM                 11.2/ 2/  11.       11.7/ 2/  12.       10.5/ 2/  11.       10.7/ 2/  11.
  CO   SAMPLE METER/RANGE/PPM                 64.9/12/ 145.       61.7/13/  60.       18.9/13/  17.       34.9/13/  32.
  CO   BCKGRD METER/RANGE/PPM                   .3/12/   1.         .8/13/   1.        1.1/13/   1.        1.6/13/   1.
  CO2  SAMPLE METER/RANGE/PCT                 17.9/ 3/  .29       25.4/ 3/  .41       57.8/ 3/ 1.02       15.9/ 3/  .25
  CO2  BCKGRD METER/RANGE/PCT                  2.2/ 3/  .03        2.4/ 3/  .04        2.2/ 3/  .03        2.1/ 3/  .03
  NOX  SAMPLE METER/RANGE/PPM                 20.1/ 2/  20.       25.5/ 2/  26.       73.2/ 2/  73.       25.1/ 2/  25.
  NOX  BCKGRD METER/RANGE/PPM                  1.0/ 2/   1.        1.1/ 2/   1.        2.1/ 2/   2.        1.7/ 2/   2.

  DILUTION FACTOR                                 44.16               31.69               13.10               52.0[illegible]
  HC   CONCENTRATION PPM                          18.                 12.                 11.                  6.
  CO   CONCENTRATION PPM                         144.                 58.                 16.                 30.
  CO2  CONCENTRATION PCT                          .25                 .38                 .99                 .22
  NOX  CONCENTRATION PPM                         19.1                24.4                71.3                23.4

  HC   MASS GRAMS                                 3.07                2.16                1.97                1.08
  CO   MASS GRAMS                                49.59               20.40                5.52               10.49
  CO2  MASS GRAMS                              1376.8              2080.6              5515.7              1202.6
  NOX  MASS GRAMS                                10.85               14.01               41.54               13.30
  FUEL KG (LB)                                 .846 (    1.86)    1.285 (    2.83)    3.556 (    7.84)     .698 (    1.54)
  KW HR (HP HR)                                1.18 (    1.58)     2.21 (    2.97)     7.52 (   10.09)     1.22 (    1.64)

  BSHC G/KW HR (G/HP HR)                       2.61 (    1.95)      .97 (     .73)      .26 (     .20)      .88 (     .66)
  BSCO G/KW HR (G/HP HR)                      42.12 (   31.41)     9.22 (    6.87)      .73 (     .55)     8.59 (    6.40)
  BSCO2 G/KW HR (G/HP HR)                   1169.43 (  872.05)   940.15 (  701.07)   733.05 (  546.63)   984.45 (  734.11)
  BSNOX G/KW HR (G/HP HR)                      9.22 (    6.88)     6.33 (    4.72)     5.52 (    4.12)    10.89 (    8.12)
  BSFC KG/KW HR (LB/HP HR)                     .718 (   1.181)     .581 (    .955)     .473 (    .777)     .571 (    .939)
TOTAL TEST RESULTS 4 BAGS                                PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          12.14 ( 16.27)                90MM FILTER
   BSHC    G/KW HR (G/HP HR)     .68 (   .51)                       SAMPLE FLOW     SCM(SCF)                 1.219 ( 43.04)
   BSCO    G/KW HR (G/HP HR)    7.09 (  5.28)                       MULTIPLIER FOR  G/TEST                    .983
   BSCO2   G/KW HR (G/HP HR)    838. (  625.)                       MULTIPLIER FOR  G/KW HR (G/HP HR)         .0810 ( .0604)
   BSNOX   G/KW HR (G/HP HR)    6.57 (  4.90)                       MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)     .1540 ( .0698)
   BSFC   KG/KW HR (LB/HP HR)   .526 (  .865)
                                                             20 X 20 FILTERS
 PART. G/KW-HR (G/HP-HR)  .20 (.15)                                SAMPLE FLOW     SCM(SCF)                 80.10 (2829.0)
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                              TABLE D-5.   ENGINE EMISSION RESULTS                                          PROJECT NO. 11-5044-301
                                               HOT TRANSIENT

ENGINE  NO.D20                             TEST NO.21-1H   RUN 1
ENGINE  MODEL   80 VOLVO DUAL FUEL         DATE 10/ 3/80
ENGINE  9.6 L(586. CID) L-6                TIME                                  DIESEL  EM-465-F
CVS NO.  10                                  DYNO NO.  5                            BAG CART NO.  1

BAROMETER 747.27 MM HG(29.42 IN HG)        RELATIVE HUMIDITY ,  ENGINE-43. PCT ,  CVS-56. PCT
DRY BULB TEMP. 27.8 DEG C(82.0 DEG F)      ABSOLUTE HUMIDITY 10.2 GM/KG( 71.2 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                     1                   2                    3                    4
  DESCRIPTION                                  NYNF                LANF                 LAF                  NYNF
  BLOWER DIF P MM. H2O(IN. H2O)            670.6 (26.4)        670.6 (26.4)         670.6 (25.4)         670.5 (26.4)
  BLOWER INLET P MM. H2O(IN. H2O)          520.7 (20.5)        520.7 (20.5)         520.7 (20.5)         520.7 (20.5)
  BLOWER INLET TEMP. DEG. C(DEG. F)         48.9 (120.0)        48.9 (120.0)         48.9 (120.0)         48.9 (120.0)
  BLOWER REVOLUTIONS                           6181.               6262.                6370.                6201.
  TIME SECONDS                                 296.0               299.9                305.0                297.0
  TOTAL FLOW STD. CU. METRES(SCF)          298.9 (10556.)      302.8 (10695.)       308.0 (10879.)       299.8 (10591.)

  HC   SAMPLE METER/RANGE/PPM              14.1/11/  14.       13.1/11/  13.         9.3/11/   9.         7.6/11/   8.
  HC   BCKGRD METER/RANGE/PPM               9.9/ 1/  10.        9.5/ 1/  10.         8.3/ 1/   8.         8.1/ 1/   8.
  CO   SAMPLE METER/RANGE/PPM              50.1/13/  47.       38.4/13/  35.         8.6/13/   8.        12.1/13/  11.
  CO   BCKGRD METER/RANGE/PPM               1.6/13/   1.        1.2/13/   1.         1.0/13/   1.          .8/13/   1.
  CO2  SAMPLE METER/RANGE/PCT              16.3/ 3/  .26       24.6/ 3/  .40        56.7/ 3/ 1.00       16.6/ 3/  .26
  CO2  BCKGRD METER/RANGE/PCT               2.8/ 3/  .04        2.8/ 3/  .04         2.8/ 3/  .04        2.8/ 3/  .04
  NOX  SAMPLE METER/RANGE/PPM               7.0/13/  21.        9.1/13/  27.        25.4/13/  76.        8.0/13/  24.
  NOX  BCKGRD METER/RANGE/PPM               1.1/ 2/   1.         .9/ 2/   1.         1.0/ 2/   1.         1.0/ 2/   1.

  DILUTION FACTOR                               50.48               33.05                13.41                50.34
  HC   CONCENTRATION PPM                          4.                  4.                   2.                  -0.
  CO   CONCENTRATION PPM                         45.                 33.                   6.                  10.
  CO2  CONCENTRATION PCT                          .22                 .36                  .96                  .22
  NOX  CONCENTRATION PPM                        19.9                26.5                 75.3                 23.2

  HC   MASS GRAMS                                 .76                 .68                  .30                 -.06
  CO   MASS GRAMS                               15.59               11.78                 2.31                 3.39
  CO2  MASS GRAMS                             1190.2              1991.4               5404.2               1221.5
  NOX  MASS GRAMS                              11.40               15.35                44.35                13.29
  FUEL KG (LB)                                 .645 (   1.42)    1.156 (   2.55)     3.309 (   7.29)      .651 (   1.44
  KW HR (HP HR)                                1.12 (   1.51)     2.03 (   2.72)      6.90 (   9.25)      1.11 (   1.48

  BSHC G/KW HR (G/HP HR)                        .68 (    .50)      .34 (    .25)       .04 (    .03)      -.05 (   -.04
  BSCO G/KW HR (G/HP HR)                      13.87 (  10.34)     5.81 (   4.33)       .34 (    .25)      3.07 (   2.29
  BSCO2 G/KW HR (G/HP HR)                   1058.66 ( 789.44)   982.36 ( 732.55)    783.70 ( 584.40)   1103.90 ( 823.18
  BSNOX G/KW HR (G/HP HR)                     10.14 (   7.56)     7.57 (   5.65)      6.43 (   4.80)     12.01 (   8.95
  BSFC KG/KW HR (LB/HP HR)                     .574 (   .944)     .570 (   .937)      .480 (   .789)      .588 (   .967

TOTAL TEST RESULTS 4 BAGS                          PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          11.15 ( 14.96)         90MM FILTER
   BSHC    G/KW HR (G/HP HR)     .15 (   .11)            SAMPLE FLOW       SCM(SCF)                     1.293 ( 45.68)
   BSCO    G/KW HR (G/HP HR)    2.97 (  2.21)            MULTIPLIER FOR    G/TEST                        .935
   BSCO2   G/KW HR (G/HP HR)    879. (  656.)            MULTIPLIER FOR    G/KW HR (G/HP HR)             .0839 ( .0625)
   BSNOX   G/KW HR (G/HP HR)    7.57 (  5.64)            MULTIPLIER FOR    G/KG FUEL (G/LB FUEL)         .1623 ( .0736)
   BSFC    KG/KW HR (LB/HP HR)  .517 (  .849)
                                                      20 X 20 FILTERS
                                                         SAMPLE FLOW       SCM(SCF)                     81.24 (2869.5)

  PART. G/KW-HR (G/HP-HR) .31 (.23)
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TABLE D-6. ENGINE EMISSION RESULTS
HOT TRANSIENT

PROJECT NO. 11-5044-001

ENGINE NO.D20
ENGINE MODEL 80 VOLVO DUAL FUEL
ENGINE 9,6 L(586. CID) L-6
CVS NO. 10

TEST NO.21-2H RUN
DATE 10/ 7/80
TIME
DYNO NO. 5

DIESEL EM-465-F
BAG CART NO. 1

BAROMETER 747.78 MM HG(29.44 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-52, PCT , CVS-47, PCT
ABSOLUTE HUMIDITY 10,1 GM/KG(70,7 GRAINS/LB) NOX HUMIDITY C.F. 1,0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
BLOWER DIF P MM. H2O(IN. H2O)	670,6 (26,4)	670,6 (26,4)	670,6 (26,4)	670,6 (26,4)
BLOWER INLET P MM. H2O(IN. H2O)	520,7 (20,5)	520,7 (20,5)	520,7 (20,6)	520,7 (20,5)
BLOWER INLET TEMP. DEG. C(DEG. F)	48,9 (120,0)	48,9 (120,0)	48,9 (120,0)	48,9 (120,0)
BLOWER REVOLUTIONS	6203.	6264.	6370.	6201.
TIME SECONDS	297,0	300,0	305,0	297,0
TOTAL FLOW STD. CU. METRES(SCF)	300,4 (10612,)	303,4 (10716,)	308,5 (10898,)	300,4 (10608,)
HC SAMPLE METER/RANGE/PPM	13,5/11/ 13.	12,8/11/ 13.	10,4/11/ 10.	9,2/11/ 9.
HC BCKGRD METER/RANGE/PPM	12,5/ 1/ 13.	11,0/ 1/ 11.	8,9/ 1/ 9.	8,3/ 1/ 8.
CO SAMPLE METER/RANGE/PPM	65,9/13/ 64.	48,7/13/ 46.	13,6/13/ 12.	20,0/13/ 18.
CO BCKGRD METER/RANGE/PPM	5,7/13/ 6.	5,9/13/ 5.	5,2/13/ 5.	4,6/13/ 4.
CO2 SAMPLE METER/RANGE/PCT	16,7/ 3/ ,27	23,6/ 3/ ,38	56,1/ 3/ ,99	16,7/ 3/ ,27
CO2 BCKGRD METER/RANGE/PCT	2,9/ 3/ ,04	2,7/ 3/ ,04	2,7/ 3/ ,04	2,6/ 3/ ,04
NOX SAMPLE METER/RANGE/PPM	6,5/13/ 20.	8,5/13/ 26.	24,7/13/ 74.	7,9/13/ 24.
NOX BCKGRD METER/RANGE/PPM	1,3/ 2/ 1.	1,3/ 2/ 1.	1,5/ 2/ 2.	1,5/ 2/ 2.
DILUTION FACTOR	48,96	34,44	13,56	49,86
HC CONCENTRATION PPM	1.	2.	2.	1.
CO CONCENTRATION PPM	58.	40.	7.	14.
CO2 CONCENTRATION PCT	.22	.34	,95	,23
NOX CONCENTRATION PPM	18,4	24,4	72,8	22,2
HC MASS GRAMS	,21	,37	.38	,19
CO MASS GRAMS	20,32	14,07	2,67	4,74
CO2 MASS GRAMS	1224,9	1907,1	5354,5	1249,4
NOX MASS GRAMS	10,55	14,14	42,98	12,78
FUEL KG (LB)	.675 (1,49)	1,117 (2,46)	3,276 (7,22)	,687 (1,51
KW HR (HP HR)	1,20 (1,61)	2,02 (2,71)	6,83 (9,16)	1,17 (1,57
BSHC G/KW HR (G/HP HR)	.18 (.13)	.19 (.14)	.06 (,04)	.16 (,12
BSCO G/KW HR (G/HP HR)	16,88 (12,59)	6,97 (5,20)	.39 (,29)	4,06 (3,02
BSCO2 G/KW HR (G/HP HR)	1017,49 (758,74)	944,93 (704,63)	783,54 (584,28)	1069,25 (797,34
BSNOX G/KW HR (G/HP HR)	8,77 (6,54)	7,01 (5,23)	6,29 (4,69)	10,94 (8,15
BSFC KG/KW HR (LB/HP HR)	.560 (,921)	,553 (,910)	.479 (.788)	,588 (,966

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)		11,22 (15,05)
BSHC	G/KW HR (G/HP HR)	.10 (,08)
BSCO	G/KW HR (G/HP HR)	3,72 (2,78)
BSCO2	G/KW HR (G/HP HR)	867. (647.)
BSNOX	G/KW HR (G/HP HR)	7,17 (5,35)
BSFC	KG/KW HR (LB/HP HR)	,513 (,843)

PART. G/KW-HR (G/HP-HR) .36 (.27)

PARTICULATE DATA, TOTAL FOR 4 BAGS

90MM FILTER

SAMPLE FLOW	SCM(SCF)	1,289 (45,54)
MULTIPLIER FOR	G/TEST	,941
MULTIPLIER FOR	G/KW HR (G/HP HR)	,0838 (,0625)
MULTIPLIER FOR	G/KG FUEL (G/LB FUEL)	,1635 (,0741)

20 X 20 FILTERS

SAMPLE FLOW	SCM(SCF)	82,55 (2915,5)

NEGATIVE TORQUE COMMAND

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TABLE D-7.   ENGINE EMISSION RESULTS                                                    PROJECT NO. 11-5044-001
                 HOT TRANSIENT

ENGINE  NO.D20                          TEST NO.21-8H  RUN
ENGINE  MODEL    80 VOLVO DUAL FUEL     DATE 10/ 9/80
ENGINE  9.6 L(586. CID) L-6             TIME 03:35                        DIESEL   EM-465-F
CVS NO.  10                              DYNO NO.  5                        BAG CART NO.  1

BAROMETER 739.90 MM HG(29.13 IN HG)     RELATIVE HUMIDITY ,  ENGINE-43. PCT ,  CVS- 0. PCT
DRY BULB TEMP. 27.8 DEG C(82.0 DEG F)   ABSOLUTE HUMIDITY 10.3 GM/KG( 72.0 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                    1                  2                  3                  4
   DESCRIPTION                                 NYNF               LANF               LAF                NYNF
   BLOWER DIF P MM. H2O(IN. H2O)          670.6 (26.4)       670.6 (26.4)       670.6 (26.4)       670.6 (26.4)
   BLOWER INLET P MM. H2O(IN. H2O)        520.7 (20.5)       520.7 (20.5)       520.7 (20.5)       520.7 (20.5)
   BLOWER INLET TEMP. DEG. C(DEG. F)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
   BLOWER REVOLUTIONS                         6182.              6265.              6371.              6203.
   TIME SECONDS                               296.0              300.0              305.0              297.0
   TOTAL FLOW STD. CU. METRES(SCF)        295.5 (10436.)     299.4 (10576.)     304.5 (10755.)     296.5 (10472.)

   HC  SAMPLE METER/RANGE/PPM              20.9/ 2/  21.      19.6/ 2/  20.      21.1/ 2/  21.      15.6/ 2/  16.
   HC  BCKGRD METER/RANGE/PPM              10.1/ 2/  10.       9.6/ 2/  10.       9.6/ 2/  10.       9.5/ 2/  10.
   CO  SAMPLE METER/RANGE/PPM              74.7/13/  74.      52.0/13/  49.      21.2/13/  19.      35.5/13/  32.
   CO  BCKGRD METER/RANGE/PPM               2.1/13/   2.       2.3/13/   2.       2.4/13/   2.       2.3/13/   2.
   CO2 SAMPLE METER/RANGE/PCT              16.7/ 3/  .27      22.9/ 3/  .37      54.9/ 3/  .96      15.8/ 3/  .25
   CO2 BCKGRD METER/RANGE/PCT               2.4/ 3/  .04       2.5/ 3/  .04       2.3/ 3/  .04       2.4/ 3/  .04
   NOX SAMPLE METER/RANGE/PPM              21.7/ 2/  22.      25.4/ 2/  25.      70.0/ 2/  70.      23.5/ 2/  24.
   NOX BCKGRD METER/RANGE/PPM               1.0/ 2/   1.       1.1/ 2/   1.       1.1/ 2/   1.       1.0/ 2/   1.

   DILUTION FACTOR                             48.63              35.44              13.87              52.37
   HC  CONCENTRATION PPM                       11.                10.                12.                 6.
   CO  CONCENTRATION PPM                       72.                47.                17.                30.
   CO2 CONCENTRATION PCT                        .23                .33                .93                .22
   NOX CONCENTRATION PPM                       20.7               24.3               69.0               22.5

   HC  MASS GRAMS                               1.88               1.77               2.14               1.07
   CO  MASS GRAMS                              24.69              16.36               5.88              10.48
   CO2 MASS GRAMS                            1245.5             1832.2             5184.9             1168.1
   NOX MASS GRAMS                              11.71              13.94              40.18              12.77
   FUEL KG (LB)                                .745 (   1.64)   1.130 (   2.49)   3.344 (   7.37)    .678 (   1.49)
   KW HR (HP HR)                               1.34 (   1.79)    2.11 (   2.83)    7.00 (   9.39)    1.21 (   1.63)

   BSHC G/KW HR (G/HP HR)                      1.40 (   1.05)     .84 (    .63)     .31 (    .23)     .89 (    .66)
   BSCO G/KW HR (G/HP HR)                     18.47 (  13.78)    7.77 (   5.79)     .84 (    .63)    8.64 (   6.44)
   BSCO2 G/KW HR (G/HP HR)                   931.83 ( 694.86)  869.68 ( 648.52)  740.49 ( 552.18)  963.21 ( 718.27)
   BSNOX G/KW HR (G/HP HR)                     8.76 (   6.53)    6.62 (   4.93)    5.74 (   4.28)   10.53 (   7.85)
   BSFC KG/KW HR (LB/HP HR)                    .557 (   .916)    .536 (   .882)    .478 (   .785)    .559 (   .919)

TOTAL TEST RESULTS 4 BAGS                            PARTICULATE DATA, TOTAL FOR 4 BAGS

   TOTAL KW HR (HP HR)         11.66 ( 15.63)           90MM FILTER
    BSHC   G/KW HR (G/HP HR)     .59 (   .44)               SAMPLE FLOW     SCM(SCF)                 1.183 ( 41.79)
    BSCO   G/KW HR (G/HP HR)    4.93 (  3.67)               MULTIPLIER FOR  G/TEST                   1.011
    BSCO2  G/KW HR (G/HP HR)    809. (  603.)               MULTIPLIER FOR  G/KW HR (G/HP HR)        .0867 ( .0647)
    BSNOX  G/KW HR (G/HP HR)    6.74 (  5.03)               MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)    .1714 ( .0778)
    BSFC  KG/KW HR (LB/HP HR)   .506 (  .832)
                                                         20 X 20 FILTERS
                                                            SAMPLE FLOW     SCM(SCF)                 79.45 (2806.0)
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PART. G/KW-HR (G/HP-HR) .25 (.19)

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                              TABLE D-8.  ENGINE EMISSION RESULTS
                                                 HOT TRANSIENT                                PROJECT NO. 11-5044-001

ENGINE   NO,D20                                  TEST NO,21-18  RUN 2
ENGINE   MODEL   80 VOLVO DUAL FUEL              DATE 10/ 3/80
ENGINE   9,6 L(586, CID) L-6                     TIME                                 DIESEL   EM-465-F
CVS NO,  10                                        DYNO NO,  5                          BAG CART NO,  1

BAROMETER 747.27 MM HG(29.42 IN HG)              RELATIVE HUMIDITY ,  ENGINE-45, PCT ,  CVS-65, PCT
DRY BULB TEMP. 27.2 DEG C(81.0 DEG F)            ABSOLUTE HUMIDITY 10,3 GM/KG( 72,2 GRAINS/LB)     NOX HUMIDITY C,F. 1,0000

BAG RESULTS
   BAG NUMBER                                          1                  2                  3
   BLOWER DIF P MM. H2O(IN. H2O)                 670.6 (26.4)       670.6 (26.4)       670.6 (26.4)
   BLOWER INLET P MM. H2O(IN. H2O)               520.7 (20.5)       520,7 (20,5)       520.7 (20.5)
   BLOWER INLET TEMP. DEG. C(DEG. F)              48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
   BLOWER REVOLUTIONS                               5694.              6009.              5692.
   TIME SECONDS                                    272.7              287.8              272.6
   TOTAL FLOW STD. CU. METRES(SCF)               275.0 ( 9713.)     290,2 (10250.)     274.9 ( 9709.)

   HC   SAMPLE METER/RANGE/PPM                   11.7/11/  12.       9.9/11/  10.       8.5/11/   8.
   HC   BCKGRD METER/RANGE/PPM                    6.5/ 1/   7.       6.5/ 1/   7.       6.2/ 1/   6.
   CO   SAMPLE METER/RANGE/PPM                   66.6/13/  65.      62.9/13/  61.      34.6/13/  32.
   CO   BCKGRD METER/RANGE/PPM                    1.0/13/   1.       1.0/13/   1.       1.1/13/   1.
   CO2  SAMPLE METER/RANGE/PCT                   19.8/ 3/  .32      24.5/ 3/  .40      19.5/ 3/  .31
   CO2  BCKGRD METER/RANGE/PCT                    2.6/ 3/  ,04       2.7/ 3/  .04       2.4/ 3/  ,04
   NOX  SAMPLE METER/RANGE/PPM                    7.6/13/  23.       9.7/13/  29.       8.2/13/  25.
   NOX  BCKGRD METER/RANGE/PPM                    1.3/ 2/   1.       1.2/ 2/   1.        .7/ 2/   1.

   DILUTION FACTOR                                   41.14              33.02              42.26
   HC   CONCENTRATION PPM                               5.                 4.                 2.
   CO   CONCENTRATION PPM                              62.                58.                30.
   CO2  CONCENTRATION PCT                              .28                .36                .28
   NOX  CONCENTRATION PPM                             21.5               28.0               23.9

   HC   MASS GRAMS                                     .85                .59                .38
   CO   MASS GRAMS                                   19.97              19.71               9.55
   CO2  MASS GRAMS                                  1407.4             1907.3             1396.4
   NOX  MASS GRAMS                                   11.33              15.52              12.56
   FUEL KG (LB)                                      .801 (    1.76)    1.158 (    2.55)     .788 (    1.74)
   KW HR (HP HR)                                     1.39 (    1.86)     2.19 (    2.93)     1.36 (    1.83)

   BSHC G/KW HR (G/HP HR)                             .61 (     .46)      .27 (     .20)      .28 (     .21)
   BSCO G/KW HR (G/HP HR)                           14.37 (   10.72)     9.02 (    6.72)     7.00 (    5.22)
   BSCO2 G/KW HR (G/HP HR)                        1012.71 (  755.18)   872.33 (  650.50)  1024.30 (  763.82)
   BSNOX G/KW HR (G/HP HR)                           8.15 (    6.08)     7.10 (    5.29)     9.21 (    6.87)
   BSFC KG/KW HR (LB/HP HR)                          .576 (    .947)     .530 (    .871)     .578 (    .950)

TOTAL TEST RESULTS 3 BAGS                              PARTICULATE DATA, TOTAL FOR 3 BAGS

   TOTAL KW HR (HP HR)             4.94 (   6.62)          90MM FILTER
    BSHC    G/KW HR (G/HP HR)       .37 (    .28)              SAMPLE FLOW       SCM(SCF)                    .895 ( 31.62)
    BSCO    G/KW HR (G/HP HR)      9.97 (   7.43)              MULTIPLIER FOR   G/TEST                       .938
    BSCO2   G/KW HR (G/HP HR)      954. (   711.)              MULTIPLIER FOR   G/KW HR (G/HP HR)            .1900 ( .1417)
    BSNOX   G/KW HR (G/HP HR)      7.98 (   5.95)              MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)        .3416 ( .1550)
    BSFC   KG/KW HR (LB/HP HR)     .556 (   .914)
                                                          20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .21 (.16)                           SAMPLE FLOW      SCM(SCF)                   55.49 (1959.8)
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TABLE D-9. ENGINE EMISSION RESULTS TRANSIENT

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                                                                                              PROJECT NO. 11-5044-001

ENGINE  NO,D20                                  TEST NO,21-28  RUN 3
ENGINE  MODEL   80 VOLVO DUAL FUEL              DATE 10/ 3/80
ENGINE  9,6 L(586, CID) L-6                     TIME                                 DIESEL   EM-465-F
CVS NO,  10                                       DYNO NO,  5                         BAG CART NO.  1

BAROMETER 747,01 MM HG(29,41 IN HG)             RELATIVE HUMIDITY ,  ENGINE-49, PCT ,  CVS-58, PCT
DRY BULB TEMP, 25,6 DEG C(78,0 DEG F)           ABSOLUTE HUMIDITY 10,2 GM/KG( 71,3 GRAINS/LB)     NOX HUMIDITY C.F. 1,0000

BAG RESULTS
   BAG NUMBER                                        1                    2                    3
   BLOWER DIF P MM, H2O(IN, H2O)                670,6 (26,4)         670,6 (26,4)         670,6 (26,4)
   BLOWER INLET P MM, H2O(IN, H2O)              520,7 (20,5)         520,7 (20,5)         520,7 (20,5)
   BLOWER INLET TEMP, DEG. C(DEG. F)             48,9 (120,0)         48,9 (120,0)         48,9 (120,0)
   BLOWER REVOLUTIONS                              5655,                6011,                5694,
   TIME SECONDS                                   272,8                287,9                272,7
   TOTAL FLOW STD, CU. METRES(SCF)              273,3 ( 9652,)       290,4 (10258,)       275,1 ( 9717,)

   HC  SAMPLE METER/RANGE/PPM                   13,6/11/  14,         9,5/11/   9,         8,2/11/   8,
   HC  BCKGRD METER/RANGE/PPM                    6,8/ 1/   7,         6,7/ 1/   7,         7,0/ 1/   7,
   CO  SAMPLE METER/RANGE/PPM                   81,3/13/  81,        64,3/13/  62,        33,8/13/  31,
   CO  BCKGRD METER/RANGE/PPM                     ,8/13/   1,          ,9/13/   1,          ,8/13/   1,
   CO2 SAMPLE METER/RANGE/PCT                   19,5/ 3/  ,31        23,5/ 3/  ,38        19,6/ 3/  ,31
   CO2 BCKGRD METER/RANGE/PCT                    2,7/ 3/  ,04         2,5/ 3/  ,04         2,5/ 3/  ,04
   NOX SAMPLE METER/RANGE/PPM                    6,7/13/  20,         8,6/13/  26,         7,4/13/  22,
   NOX BCKGRD METER/RANGE/PPM                     ,8/ 2/   1,          ,6/ 2/   1,          ,7/ 2/   1,

   DILUTION FACTOR                                 41,56                34,48                42,05
   HC  CONCENTRATION PPM                              7,                   3,                   1,
   CO  CONCENTRATION PPM                             79,                  60,                  29,
   CO2 CONCENTRATION PCT                             ,27                  ,34                  ,28
   NOX CONCENTRATION PPM                            19,3                 25,1                 21,5

   HC  MASS GRAMS                                   1,10                  ,49                  ,21
   CO  MASS GRAMS                                  25,02                20,31                 9,41
   CO2 MASS GRAMS                                 1365,5               1832,3               1398,4
   NOX MASS GRAMS                                  10,10                13,93                11,31
   FUEL KG (LB)                                    ,807 (   1,78)      1,116 (   2,46)       ,786 (   1,73)
   KW HR (HP HR)                                   1,43 (   1,91)       2,21 (   2,97)       1,38 (   1,85)

   BSHC G/KW HR (G/HP HR)                           ,77 (    ,58)        ,22 (    ,17)        ,16 (    ,12)
   BSCO G/KW HR (G/HP HR)                         17,55 (  13,09)       9,18 (   6,84)       6,82 (   5,08)
   BSCO2 G/KW HR (G/HP HR)                       958,15 ( 714,49)     827,96 ( 617,41)    1012,67 ( 755,15)
   BSNOX G/KW HR (G/HP HR)                         7,09 (   5,29)       6,30 (   4,69)       8,19 (   6,11)
   BSFC KG/KW HR (LB/HP HR)                        ,566 (   ,931)       ,504 (   ,829)       ,569 (   ,936)

TOTAL TEST RESULTS 3 BAGS                                  PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)             5,02 (  6,73)                90MM FILTER
   BSHC    G/KW HR (G/HP HR)       ,36 (   ,27)                     SAMPLE FLOW      SCM(SCF)                     ,898 ( 31,72)
   BSCO    G/KW HR (G/HP HR)     10,91 (  8,13)                     MULTIPLIER FOR  G/TEST                        ,934
   BSCO2   G/KW HR (G/HP HR)      916, (  683,)                     MULTIPLIER FOR  G/KW HR (G/HP HR)             ,1861 ( ,1388)
   BSNOX   G/KW HR (G/HP HR)      7,04 (  5,25)                     MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)         ,3447 ( ,1564)
   BSFC   KG/KW HR (LB/HP HR)     ,540 (  ,888)
                                                               20 X 20 FILTERS
                                                                    SAMPLE FLOW      SCM(SCF)                     56,15 (1983,3)
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Part. G/KW-HR (G/HP-HR) .21 (.16)

*Est. BSNOX G/KW-HR (G/HP-HR) 8.03 (5.99)

TABLE D-10. ENGINE EMISSION RESULTS
C-TRANS.

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                                                                                              PROJECT NO. 11-5044-001
ENGINE  NO.D20                               TEST NO.D21-1  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL            DATE 11/14/80
ENGINE  9.6 L(586. CID) L-6                  TIME 10:00
CVS NO.  10                                                                 DIESEL   EM-465-F
                                               DYNO NO.  5                   BAG CART NO.  1
BAROMETER 739.65 MM HG(29.12 IN HG)
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)        RELATIVE HUMIDITY ,  ENGINE-65. PCT ,  CVS-45. PCT
                                             ABSOLUTE HUMIDITY 10.8 GM/KG( 75.6 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000
BAG RESULTS
  BAG NUMBER                                     1                     2                     3                     4
  DESCRIPTION                                  NYNF                  LANF                   LAF                  NYNF
  BLOWER DIF P MM. H2O(IN. H2O)           680.7 (26.8)          680.7 (26.8)          680.7 (26.8)          680.7 (26.8)
  BLOWER INLET P MM. H2O(IN. H2O)         525.8 (20.7)          525.8 (20.7)          525.8 (20.7)          525.8 (20.7)
  BLOWER INLET TEMP. DEG. C(DEG. F)        48.9 (120.0)          48.9 (120.0)          48.9 (120.0)          48.9 (120.0)
  BLOWER REVOLUTIONS                         6183.                 6264.                 6371.                 6202.
  TIME SECONDS                               296.0                 300.0                 305.0                 297.0
  TOTAL FLOW STD. CU. METRES(SCF)         295.6 (10440.)        299.4 (10577.)        304.6 (10757.)        296.5 (10472.)

  HC  SAMPLE METER/RANGE/PPM              24.3/21/  24.         19.6/21/  20.         19.8/21/  20.         13.6/21/  14.
  HC  BCKGRD METER/RANGE/PPM              12.3/ 1/  12.         12.2/ 1/  12.         12.0/ 1/  12.         10.7/ 1/  11.
  CO  SAMPLE METER/RANGE/PPM              52.6/12/ 112.         46.7/13/  44.         19.6/13/  18.         34.8/13/  32.
  CO  BCKGRD METER/RANGE/PPM               1.0/12/   2.          2.2/13/   2.          2.0/13/   2.          1.7/13/   2.
  CO2 SAMPLE METER/RANGE/PCT              20.6/ 3/  .33         27.6/ 3/  .45         62.2/ 3/ 1.11         24.1/ 3/  .39
  CO2 BCKGRD METER/RANGE/PCT               3.6/ 3/  .06          3.5/ 3/  .05          3.1/ 3/  .05          3.2/ 3/  .05
  NOX SAMPLE METER/RANGE/PPM               8.8/13/  26.         10.5/13/  31.         27.6/13/  83.         11.7/13/  35.
  NOX BCKGRD METER/RANGE/PPM                .6/ 2/   1.           .5/ 2/   1.           .5/ 2/   1.           .4/ 2/   0.

  DILUTION FACTOR                             38.81                 29.17                 12.07                 33.80
  HC  CONCENTRATION PPM                        12.                    8.                    9.                    3.
  CO  CONCENTRATION PPM                       108.                   41.                   16.                   30.
  CO2 CONCENTRATION PCT                        .28                   .40                  1.06                   .34
  NOX CONCENTRATION PPM                       25.8                  30.9                  82.4                  34.8

  HC  MASS GRAMS                              2.10                  1.35                  1.55                   .55
  CO  MASS GRAMS                             37.26                 14.28                  5.52                 10.36
  CO2 MASS GRAMS                            1505.2                2200.9                5930.5                1870.1
  NOX MASS GRAMS                             14.61                 17.71                 48.01                 19.74
  FUEL KG (LB)                            .872 (   1.92)      1.263 (   2.79)      3.629 (   8.00)      1.059 (   2.33)
  KW HR (HP HR)                           1.09 (   1.46)       1.98 (   2.66)       6.76 (   9.07)       1.05 (   1.41)

  BSHC G/KW HR (G/HP HR)                  1.92 (   1.43)        .68 (    .51)        .23 (    .17)        .52 (    .39)
  BSCO G/KW HR (G/HP HR)                 34.15 (  25.47)       7.20 (   5.37)        .82 (    .61)       9.82 (   7.32)
  BSCO2 G/KW HR (G/HP HR)              1379.58 (1028.75)    1109.46 ( 827.32)     876.94 ( 653.94)    1772.61 (1321.84)
  BSNOX G/KW HR (G/HP HR)                13.39 (   9.98)       8.93 (   6.66)       7.10 (   5.29)      18.71 (  13.96)
  BSFC KG/KW HR (LB/HP HR)                .799 (  1.313)       .637 (  1.047)       .537 (   .882)      1.003 (  1.650)

TOTAL TEST RESULTS 4 BAGS                               PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)            10.89 ( 14.61)              90MM FILTER
   BSHC    G/KW HR (G/HP HR)       .51 (   .38)                 SAMPLE FLOW      SCM(SCF)                     1.223 ( 43.21)
   BSCO    G/KW HR (G/HP HR)      6.19 (  4.62)                 MULTIPLIER FOR   G/TEST                        .978
   BSCO2   G/KW HR (G/HP HR)     1056. (  788.)                 MULTIPLIER FOR   G/KW HR (G/HP HR)            .0898 ( .0669)
   BSNOX   G/KW HR (G/HP HR)      9.19 (  6.85)                 MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)        .1433 ( .0650)
   BSFC  KG/KW HR (LB/HP HR)      .626 ( 1.030)
                                                             20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .30 (.22)                              SAMPLE FLOW    SCM(SCF)                     81.09 (2864.0)
```

TABLE D-11. ENGINE EMISSION RESULTS C-TRANS.

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                                                                                      PROJECT NO. 11-5044-001

ENGINE  NO.D20                                  TEST NO.21-2C  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL               DATE 11/17/80
ENGINE  9.6 L(586. CID) L-6                     TIME 10:47                        DIESEL   EM-465-F
CVS NO.  10                                       DYNO NO.  5                      BAG CART NO.  1

BAROMETER 747.52 MM HG(29.43 IN HG)             RELATIVE HUMIDITY ,  ENGINE-72. PCT ,  CVS-25. PCT
DRY BULB TEMP. 18.3 DEG C(65.0 DEG F)           ABSOLUTE HUMIDITY  9.6 GM/KG( 67.3 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                          1                  2                  3                  4
  DESCRIPTION                                       NYNF               LANF                LAF               NYNF
  BLOWER DIF P MM. H2O(IN. H2O)                685.8 (27.0)       685.8 (27.0)       685.8 (27.0)       685.8 (27.0)
  BLOWER INLET P MM. H2O(IN. H2O)              530.9 (20.9)       530.9 (20.9)       530.9 (20.9)       530.9 (20.9)
  BLOWER INLET TEMP. DEG. C(DEG. F)             47.8 (118.0)       47.8 (118.0)       47.8 (118.0)       47.8 (118.0)
  BLOWER REVOLUTIONS                               6180.              6265.              6372.              6203.
  TIME SECONDS                                    295.9              300.0              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)              299.5 (10580.)     303.7 (10725.)     308.8 (10903.)     300.7 (10617.)

  HC   SAMPLE METER/RANGE/PPM                  21.6/21/  22.      18.9/21/  19.      20.3/21/  20.      11.4/21/  11.
  HC   BCKGRD METER/RANGE/PPM                   6.6/ 1/   7.       8.3/ 1/   8.       8.3/ 1/   8.       8.3/ 1/   8.
  CO   SAMPLE METER/RANGE/PPM                  49.6/12/ 105.      40.8/13/  38.      16.6/13/  15.      25.5/13/  23.
  CO   BCKGRD METER/RANGE/PPM                    .2/12/   0.        .7/13/   1.        .8/13/   1.        .8/13/   1.
  CO2  SAMPLE METER/RANGE/PCT                  20.4/ 3/  .33      29.1/ 3/  .48      57.4/ 3/ 1.01      18.0/ 3/  .30
  CO2  BCKGRD METER/RANGE/PCT                   2.7/ 3/  .04       2.7/ 3/  .04       2.8/ 3/  .04       3.0/ 3/  .05
  NOX  SAMPLE METER/RANGE/PPM                   8.1/13/  24.      10.3/13/  31.      24.7/13/  74.       8.8/13/  26.
  NOX  BCKGRD METER/RANGE/PPM                   1.1/ 2/   1.        .9/ 2/   1.        .7/ 2/   1.        .8/ 2/   1.

  DILUTION FACTOR                                 39.30              27.61              13.20              43.97
  HC   CONCENTRATION PPM                          15.                11.                13.                 3.
  CO   CONCENTRATION PPM                         103.                37.                14.                22.
  CO2  CONCENTRATION PCT                           .29                .44                .97                .26
  NOX  CONCENTRATION PPM                          23.3               30.1               73.4               25.5

  HC   MASS GRAMS                                 2.61               1.90               2.24                .57
  CO   MASS GRAMS                                35.94              12.99               5.03               7.81
  CO2  MASS GRAMS                               1581.0             2446.1             5497.0             1412.1
  NOX  MASS GRAMS                                13.36              17.48              43.38              14.69
  FUEL KG (LB)                                   .895 (   1.97)   1.412 (   3.11)   3.327 (   7.34)    .734 (   1.62)
  KW HR (HP HR)                                   .99 (   1.33)    1.85 (   2.48)    6.44 (   8.63)    1.05 (   1.41)

  BSHC G/KW HR (G/HP HR)                         2.63 (   1.96)    1.03 (    .77)     .35 (    .26)     .54 (    .40)
  BSCO G/KW HR (G/HP HR)                        36.24 (  27.02)    7.03 (   5.24)     .78 (    .58)    7.40 (   5.52)
  BSCO2 G/KW HR (G/HP HR)                     1593.92 (1188.59) 1323.31 ( 986.79)  853.82 ( 636.69) 1338.47 ( 998.10)
  BSNOX G/KW HR (G/HP HR)                       13.47 (  10.04)    9.46 (   7.05)    6.74 (   5.02)   13.93 (  10.38)
  BSFC KG/KW HR (LB/HP HR)                       .702 (  1.483)    .764 (  1.255)    .517 (   .850)    .695 (  1.143)

TOTAL TEST RESULTS 4 BAGS                             PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)           10.33 ( 13.36)            90MM FILTER
   BSHC   G/KW HR (G/HP HR)       .71 (   .53)               SAMPLE FLOW      SCM(SCF)                  1.286 ( 45.41)
   BSCO   G/KW HR (G/HP HR)      5.98 (  4.46)               MULTIPLIER FOR   G/TEST                     .743
   BSCO2  G/KW HR (G/HP HR)     1058. (  789.)               MULTIPLIER FOR   G/KW HR (G/HP HR)          .0913 ( .0681)
   BSNOX  G/KW HR (G/HP HR)      8.60 (  6.42)               MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)      .1481 ( .0672)
   BSFC  KG/KW HR (LB/HP HR)     .616 ( 1.013)
                                                          20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .27 (.20)                           SAMPLE FLOW      SCM(SCF)                  82.71 (2921.2)
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TABLE D-12. ENGINE EMISSION RESULTS

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                                         H-TRANS.                                 PROJECT NO. 11-5044-001

ENGINE   NO.D20                            TEST NO.D21-1  RUN1
ENGINE   MODEL   80 VOLVO DUALFUEL         DATE 11/14/80
ENGINE   9.6 L(586. CID) L-6               TIME 10:50                        DIESEL   EM-465-F
CVS NO.  10                                  DYNO NO.  5                       BAG CART NO.  1

BAROMETER 739.14 MM HG(29.10 IN HG)        RELATIVE HUMIDITY ,  ENGINE-43. PCT ,  CVS-45. PCT
DRY BULB TEMP. 28.3 DEG C(83.0 DEG F)      ABSOLUTE HUMIDITY 10.6 GM/KG( 74.4 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                     1                    2                    3                    4
  DESCRIPTION                                  NYNF                 LANF                 LAF                  NYNF
  BLOWER DIF P MM. H2O(IN. H2O)            680.7 (26.8)         680.7 (26.8)         680.7 (26.8)         680.7 (26.8)
  BLOWER INLET P MM. H2O(IN. H2O)          525.8 (20.7)         525.3 (20.7)         525.8 (20.7)         525.8 (20.7)
  BLOWER INLET TEMP. DEG. C(DEG. F)         48.9 (120.0)         48.9 (120.0)         48.9 (120.0)         48.9 (120.0)
  BLOWER REVOLUTIONS                          6180.                6265.                6371.                6202.
  TIME SECONDS                               296.0                300.0                305.0                297.0
  TOTAL FLOW STD. CU. METRES(SCF)          295.1 (10421.)       299.1 (10565.)       304.2 (10743.)       296.1 (10459.)

  HC   SAMPLE METER/RANGE/PPM              15.3/21/  15.        15.1/21/  15.        18.2/21/  18.        12.3/21/  12.
  HC   BCKGRD METER/RANGE/PPM              12.8/ 1/  13.        12.3/ 1/  12.        11.8/ 1/  12.        12.1/ 1/  12.
  CO   SAMPLE METER/RANGE/PPM              51.8/13/  49.        34.3/13/  32.        19.2/13/  17.        30.1/13/  28.
  CO   BCKGRD METER/RANGE/PPM               1.1/13/   1.         1.1/13/   1.         1.0/13/   1.         1.1/13/   1.
  CO2  SAMPLE METER/RANGE/PCT              19.7/ 3/  .32        27.4/ 3/  .45        62.9/ 3/ 1.12        21.7/ 3/  .35
  CO2  BCKGRD METER/RANGE/PCT               3.0/ 3/  .05         2.9/ 3/  .04         3.0/ 3/  .05         3.5/ 3/  .05
  NOX  SAMPLE METER/RANGE/PPM               8.4/13/  25.        10.8/13/  32.        28.0/13/  84.        11.1/13/  33.
  NOX  BCKGRD METER/RANGE/PPM                .7/ 2/   1.          .6/ 2/   1.          .7/ 2/   1.          .6/ 2/   1.

  DILUTION FACTOR                             41.50                29.50                11.92                37.79
  HC   CONCENTRATION PPM                       3.                   3.                   7.                   0.
  CO   CONCENTRATION PPM                      47.                  30.                  16.                  26.
  CO2  CONCENTRATION PCT                       .27                  .41                 1.08                  .30
  NOX  CONCENTRATION PPM                      24.4                 31.7                 83.2                 32.6

  HC   MASS GRAMS                               .47                  .56                 1.30                  .08
  CO   MASS GRAMS                             16.16                10.45                 5.67                 9.01
  CO2  MASS GRAMS                           1463.4               2228.1               6009.1               1618.2
  NOX  MASS GRAMS                             13.78                18.12                48.42                18.45
  FUEL KG (LB)                               .804 (   1.77)     1.286 (   2.83)     3.701 (   8.16)      .879 (   1.94)
  KW HR (HP HR)                              1.16 (   1.56)      2.04 (   2.73)      7.00 (   9.38)      1.17 (   1.57)

  BSHC  G/KW HR (G/HP HR)                     .41 (    .30)       .27 (    .20)       .19 (    .14)       .07 (    .05)
  BSCO  G/KW HR (G/HP HR)                   13.89 (  10.36)      5.13 (   3.82)       .81 (    .60)      7.69 (   5.73)
  BSCO2 G/KW HR (G/HP HR)                 1262.38 ( 941.35)  1093.37 ( 815.32)    858.80 ( 640.41)   1380.44 (1029.40)
  BSNOX G/KW HR (G/HP HR)                   11.85 (   8.84)      8.89 (   6.63)      6.92 (   5.16)     15.74 (  11.74)
  BSFC  KG/KW HR (LB/HP HR)                  .691 (  1.136)      .631 (  1.037)      .529 (   .870)      .750 (  1.233)

TOTAL TEST RESULTS 4 BAGS                        PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)        11.37 ( 15.25)         90MM FILTER
   BSHC   G/KW HR (G/HP HR)    .21 (   .16)            SAMPLE FLOW      SCM(SCF)                   1.236 ( 43.67)
   BSCO   G/KW HR (G/HP HR)   3.63 (  2.71)            MULTIPLIER FOR   G/TEST                      .966
   BSCO2  G/KW HR (G/HP HR)   996. (  743.)            MULTIPLIER FOR   G/KW HR (G/HP HR)          .0850 ( .0634)
   BSNOX  G/KW HR (G/HP HR)   8.57 (  6.40)            MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)      .1448 ( .0657)
   BSFC  KG/KW HR (LB/HP HR)  .587 (  .964)
                                                    20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .40 (.30)                     SAMPLE FLOW     SCM(SCF)                   80.39 (2839.4)
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                                 TABLE D-13.  ENGINE EMISSION RESULTS
                                                  H-TRANS.                                          PROJECT NO. 11-5044-001

ENGINE  NO.D20                                  TEST NO.D21-2  RUN1
ENGINE  MODEL   00 VOLVO DUALFUEL               DATE 11/14/80
ENGINE  9.6 L(586. CID) L-6                     TIME 11:35                              DIESEL   EM-465-F
CVS NO.  10                                       DYNO NO.  5                             BAG CART NO.  1

BAROMETER 740.16 MM HG(29.14 IN HG)             RELATIVE HUMIDITY ,  ENGINE-46. PCT ,  CVS-45. PCT
DRY BULB TEMP. 27.2 DEG C(81.0 DEG F)           ABSOLUTE HUMIDITY 10.5 GM/KG( 73.7 GRAINS/LB)        NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                          1                  2                  3                  4
  DESCRIPTION                                        NYNF               LANF               LAF                NYNF
  BLOWER DIF P MM. H2O(IN. H2O)                 680.7 (26.8)       680.7 (26.8)       680.7 (26.8)       680.7 (26.8)
  BLOWER INLET P MM. H2O(IN. H2O)               525.8 (20.7)       525.8 (20.7)       525.8 (20.7)       525.8 (20.7)
  BLOWER INLET TEMP. DEG. C(DEG. F)              50.0 (122.0)       50.0 (122.0)       50.0 (122.0)       50.0 (122.0)
  BLOWER REVOLUTIONS                                6182.              6264.              6371.              6201.
  TIME SECONDS                                      296.0              300.0              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)               294.8 (10412.)     298.7 (10550.)     303.8 (10730.)     295.7 (10444.)

  HC  SAMPLE METER/RANGE/PPM                    12.8/21/  13.      13.5/21/  13.      17.3/21/  17.      10.1/21/  10.
  HC  BCKGRD METER/RANGE/PPM                    10.2/ 1/  10.      10.3/ 1/  10.      11.5/ 1/  12.      10.3/ 1/  10.
  CO  SAMPLE METER/RANGE/PPM                    48.4/13/  46.      31.4/13/  29.      20.6/13/  19.      28.3/13/  26.
  CO  BCKGRD METER/RANGE/PPM                     2.2/13/   2.       2.2/13/   2.       1.8/13/   2.       1.9/13/   2.
  CO2 SAMPLE METER/RANGE/PCT                    19.5/ 3/  .31      26.9/ 3/  .44      61.2/ 3/ 1.09      20.0/ 3/  .32
  CO2 BCKGRD METER/RANGE/PCT                     3.7/ 3/  .06       3.6/ 3/  .06       4.1/ 3/  .06       3.7/ 3/  .06
  NOX SAMPLE METER/RANGE/PPM                     7.7/13/  23.       8.9/13/  27.      27.1/13/  81.       7.6/13/  29.
  NOX BCKGRD METER/RANGE/PPM                      .8/ 2/   1.        .8/ 2/   1.        .9/ 2/   1.        .9/ 2/   1.

  DILUTION FACTOR                                   42.02              30.11              12.29              41.21
  HC  CONCENTRATION PPM                               3.                 4.                 7.                 0.
  CO  CONCENTRATION PPM                              43.                26.                17.                24.
  CO2 CONCENTRATION PCT                              .26                .39               1.03                .27
  NOX CONCENTRATION PPM                             22.3               26.0               80.3               28.1

  HC  MASS GRAMS                                     .48                .61               1.18                .01
  CO  MASS GRAMS                                   14.66               9.17               5.88               8.19
  CO2 MASS GRAMS                                  1391.6             2119.5             5724.9             1441.9
  NOX MASS GRAMS                                   12.56              14.86              46.68              15.88
  FUEL KG (LB)                                   .756 (   1.67)   1.215 (   2.68)   3.495 (   7.71)    .758 (   1.67)
  KW HR (HP HR)                                  1.20 (   1.61)    2.05 (   2.74)    6.93 (   9.29)    1.18 (   1.58)

  BSHC G/KW HR (G/HP HR)                          .40 (    .30)     .30 (    .22)     .17 (    .13)     .01 (    .01)
  BSCO G/KW HR (G/HP HR)                        12.23 (   9.12)    4.43 (   3.34)     .85 (    .63)    6.93 (   5.17)
  BSCO2 G/KW HR (G/HP HR)                     1160.36 ( 865.28) 1035.47 ( 772.15)  826.70 ( 616.47) 1220.69 ( 910.27)
  BSNOX G/KW HR (G/HP HR)                       10.48 (   7.81)    7.26 (   5.41)    6.74 (   5.03)   13.44 (  10.02)
  BSFC KG/KW HR (LB/HP HR)                       .631 (  1.037)    .594 (   .976)    .505 (   .830)    .642 (  1.055)

TOTAL TEST RESULTS 4 BAGS                                   PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)             11.35 ( 15.22)               90MM FILTER
   BSHC   G/KW HR (G/HP HR)         .20 (   .15)                  SAMPLE FLOW       SCM(SCF)                  1.242 ( 43.86)
   BSCO   G/KW HR (G/HP HR)        3.34 (  2.49)                  MULTIPLIER FOR    G/TEST                     .961
   BSCO2  G/KW HR (G/HP HR)        941. (  701.)                  MULTIPLIER FOR    G/KW HR (G/HP HR)          .0846 ( .0631)
   BSNOX  G/KW HR (G/HP HR)        7.93 (  5.91)                  MULTIPLIER FOR    G/KG FUEL (G/LB FUEL)      .1543 ( .0700)
   BSFC  KG/KW HR (LB/HP HR)       .548 (  .901)
                                                               20 X 20 FILTERS
  PART. G/KW-HR (G/HP-HR)  .42 (.31)                              SAMPLE FLOW      SCM(SCF)                   79.94 (2823.5)
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TABLE D-14. ENGINE EMISSION RESULTS
H-TRANS.

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                                                                                            PROJECT NO. 11-5044-001
ENGINE  NO.D20                               TEST NO.D21-1  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL            DATE 11/14/80
ENGINE  9.6 L(586. CID) L-6                  TIME 12:30                            DIESEL   EM-465-F
CVS NO.  10                                    DYNO NO.  5                           BAG CART NO.  1

BAROMETER 739.65 MM HG(29.12 IN HG)          RELATIVE HUMIDITY ,  ENGINE-48. PCT ,  CVS-45. PCT
DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)        ABSOLUTE HUMIDITY 10.8 GM/KG( 75.4 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                       1                  2                  3
  BLOWER DIF P MM. H2O(IN. H2O)              680.7 (26.8)       680.7 (26.8)       680.7 (26.8)
  BLOWER INLET P MM. H2O(IN. H2O)            525.8 (20.7)       525.8 (20.7)       525.8 (20.7)
  BLOWER INLET TEMP. DEG. C(DEG. F)           50.0 (122.0)       50.0 (122.0)       50.0 (122.0)
  BLOWER REVOLUTIONS                           5694.              6011.              5694.
  TIME SECONDS                                 272.6              287.8              272.7
  TOTAL FLOW STD. CU. METRES(SCF)            271.3 ( 9582.)     286.4 (10116.)     271.3 ( 9582.)

  HC   SAMPLE METER/RANGE/PPM                14.2/21/  14.      11.6/21/  12.       9.2/21/   9.
  HC   BCKGRD METER/RANGE/PPM                 9.3/ 1/   9.       8.3/ 1/   8.       8.7/ 1/   9.
  CO   SAMPLE METER/RANGE/PPM                64.8/13/  63.      54.0/13/  51.      35.6/13/  33.
  CO   BCKGRD METER/RANGE/PPM                 1.9/13/   2.       2.0/13/   2.       2.0/13/   2.
  CO2  SAMPLE METER/RANGE/PCT                21.8/ 3/  .35      26.6/ 3/  .44      22.4/ 3/  .36
  CO2  BCKGRD METER/RANGE/PCT                 3.8/ 3/  .06       3.5/ 3/  .05       3.5/ 3/  .05
  NOX  SAMPLE METER/RANGE/PPM                 8.2/13/  25.      11.6/13/  35.       9.2/13/  28.
  NOX  BCKGRD METER/RANGE/PPM                  .9/ 2/   1.       1.0/ 2/   1.       1.0/ 2/   1.

  DILUTION FACTOR                               37.24              30.34              36.54
  HC   CONCENTRATION PPM                         5.                 4.                 1.
  CO   CONCENTRATION PPM                        60.                48.                31.
  CO2  CONCENTRATION PCT                         .30                .38                .31
  NOX  CONCENTRATION PPM                        23.7               33.7               26.6

  HC   MASS GRAMS                                .80                .58                .11
  CO   MASS GRAMS                              18.82              16.13               9.64
  CO2  MASS GRAMS                             1468.7             2012.4             1542.5
  NOX  MASS GRAMS                              12.29              18.47              13.80
  FUEL KG (LB)                                 .836 (   1.84)    1.189 (   2.62)     .833 (   1.84)
  KW HR (HP HR)                                1.34 (   1.80)     2.16 (   2.90)     1.33 (   1.79)

  BSHC G/KW HR (G/HP HR)                        .59 (    .44)      .27 (    .20)      .09 (    .06)
  BSCO G/KW HR (G/HP HR)                      14.01 (  10.45)     7.45 (   5.56)     7.22 (   5.39)
  BSCO2 G/KW HR (G/HP HR)                   1093.18 ( 815.18)   929.92 ( 693.44)  1155.85 ( 861.92)
  BSNOX G/KW HR (G/HP HR)                      9.15 (   6.82)     8.53 (   6.36)    10.34 (   7.71)
  BSFC KG/KW HR (LB/HP HR)                     .623 (  1.023)     .550 (   .903)     .624 (  1.026)

TOTAL TEST RESULTS 3 BAGS                         PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)            4.84 (  6.49)       90MM FILTER
  BSHC   G/KW HR (G/HP HR)        .31 (   .23)            SAMPLE FLOW       SCM(SCF)                    .866 ( 30.58)
  BSCO   G/KW HR (G/HP HR)       9.21 (  6.87)            MULTIPLIER FOR    G/TEST                      .958
  BSCO2  G/KW HR (G/HP HR)      1037. (  774.)            MULTIPLIER FOR    G/KW HR (G/HP HR)           .1978 ( .1475)
  BSNOX  G/KW HR (G/HP HR)       9.20 (  6.86)            MULTIPLIER FOR    G/KG FUEL (G/LB FUEL)       .3350 ( .1519)
  BSFC   KG/KW HR (LB/HP HR)     .590 (  .971)
                                                     20 X 20 FILTERS
 PART. G/KW-HR (G/HP-HR) .24 (.18)                        SAMPLE FLOW      SCM(SCF)                     55.51 (1960.7)
```

APPENDIX E

TRANSIENT TEST RESULTS FROM THE ETHANOL CONFIGURATION

TABLE E-1. NOTES CONCERNING TEST RESULTS GIVEN IN APPENDIX E

Table No.	Notes
Ethanol	
	Volvo requested runs to verify the influence of high flow diesel actuation and the influence of the actual start up "puff" on particulate measurement. E-1, E-2 and E-3 are a very limited series and were conducted using a negative torque command to insure reliable diesel solenoid operation.
E-2	Passed statistical requirements. Particulate sampling conducted as normal. Diesel fuel flow would switch to "high" flow at closed throttle conditions. Particulate rate by 90mm and by 20X20 inch filter samples yielded 0.30 and 0.27 g/bhp-hr respectively. Results not used for regulated emissions.
E-3	Passed statistical requirements. The 90mm particulate system was activated 10 seconds after engine start-up/cycle start-up. Particulate rate by 90 mm and by 20X20 inch filter sample yielded 0.25 and 0.26 g/bhp-hr, respecitvely. Results not used for regulated emissions.
E-4	Passed statistical requirements. Particulate sampling conducted as normal but the diesel fuel flow was switched to "low" flow throughout the test. Particulate rate by 90mm and by 20X20 inch filter samples yielded 0.30 and 0.26 g/bhp-hr, respectively. Results not used for regulated emissions. Volvo perferred that the "low" flow setting be used on subsequent runs.
Cold Start	
E-5	Failed statistical requirements. Used standard "0" torque command control. Torque intercept, -15.5. Results used for emissions.
E-6	Volvo requested that diesel fuel flow be set to "low" flow even for cold start-up. Engine false started on "low" fuel flow, dynamometer engaged. Passed statistical requirements. Results used for regulated emissions. NO_x by bag measurement was 7.20 g/kW-hr.
E-7	It was agreed that "high" flow diesel would be used for the first 23 seconds then switched to low flow. Failed statistical requirements, torque intercept -15.4. Results used for regulated emissions.
E-8	Failed statistical requirements, torque intercept -18.1, power slope 1.4 percent high. Results used for regulated emissions. NO_x by bag measurement was 7.09 g/kW-hr.
E-9	Failed statistical requirements, torque intercept -20.8. Results used for regulated emissions

TABLE E-1 (CONT'D). NOTES CONCERNING TEST RESULTS GIVEN IN APPENDIX E

Table No.	Notes
E-10	Failed statistical requirements, torque and power slope .5 and 4.4 percent high. Run primarily for additional chemistry samples. Results used for regulated emissions.
Hot Start	
E-11	Same as E-5, but passed statistical requirements. Results used for regulated emissions.
E-12	Same as E-6, but failed statistical requirements - torque r^2 2 percent low. Results used for regulated emissions.
E-13	Failed statistical requirements, torque intercept -16.1. Results used for regulated emissions.
E-14	Failed statistical requirements, torque intercept -18.1 and power slope 1.4 percent high. Results used for regulated emissions.
E-15	Failed statistical requirements, torque intercept -20.2. Results used for regulated emissions. NO_x by bag measurement was 7.12 g/kW-hr.
E-16	Passed statistical requirements. Run primarily for additional chemistry samples. Results used for regulated emissions. NO_x by bag measurement was 7.20 g/kW-hr.
Bus Cycle	
E-17	Failed statistical requirements, torque intercept -16.4. Results used for regulated emissions. NO_x by bag measurement was 8.39 g/kW-hr.
E-18	Failed statistical requirements, torque r^2 4 percent low. Results used for regulated emissions. NO_x by bag measurement was 8.22 g/kW-hr.
E-19	Failed statistical requirements, torque intercept and r^2 were -17.6 and .816, respectively. Results used for regulated emissions.
E-20	Failed statistical requirements, torque r^2 1 percent low. Run primarily for chemistry samples. Results used for regulated emissions.

TABLE E-2.

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                                        ENGINE EMISSION RESULTS
                                              HOT TRANSIENT                                      PROJECT NO. 11-5044-001

ENGINE  NO. D20                                 TEST NO.22-1H  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL              DATE 10/15/80
ENGINE  9.6 L(586. CID) L-6                     TIME                                DIESEL   EM-465-F
CVS NO.  10                                       DYNO NO.  5                         BAG CART NO.  1

BAROMETER 733.81 MM HG(28.89 IN HG)             RELATIVE HUMIDITY ,  ENGINE-48. PCT ,  CVS-48. PCT
DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)           ABSOLUTE HUMIDITY 10.5 GM/KG( 73.8 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                        1                 2                  3                  4
   DESCRIPTION                                     NYNF              LANF               LAF                NYNF
   BLOWER DIF P MM. H2O(IN. H2O)              673.1 (26.5)      673.1 (26.5)       673.1 (26.5)       673.1 (26.5)
   BLOWER INLET P MM. H2O(IN. H2O)            520.7 (20.5)      520.7 (20.5)       520.7 (20.5)       520.7 (20.5)
   BLOWER INLET TEMP. DEG. C(DEG. F)           48.9 (120.0)      48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
   BLOWER REVOLUTIONS                            6182.             6263.              6371.              6201.
   TIME SECONDS                                  296.0             299.7              305.0              297.0
   TOTAL FLOW STD. CU. METRES(SCF)            292.9 (10345.)    296.7 (10481.)     301.9 (10661.)     293.8 (10377.)

   HC   SAMPLE METER/RANGE/PPM                6.7/22/  34.      8.1/22/  41.      13.7/22/  69.       5.8/22/  29.
   HC   BCKGRD METER/RANGE/PPM                9.4/ 1/   9.      7.4/ 1/   7.       7.5/ 1/   8.       7.0/ 1/   7.
   CO   SAMPLE METER/RANGE/PPM               96.5/13/  98.     54.3/12/ 117.      65.8/12/ 147.      83.7/13/  84.
   CO   BCKGRD METER/RANGE/PPM                 .7/13/   1.       .4/12/   1.        .4/12/   1.        .9/13/   1.
   CO2  SAMPLE METER/RANGE/PCT               16.4/ 3/  .26     26.2/ 3/  .43      60.4/ 3/ 1.07      16.7/ 3/  .27
   CO2  BCKGRD METER/RANGE/PCT                2.7/ 3/  .04      2.7/ 3/  .04       2.7/ 3/  .04       2.6/ 3/  .04
   NOX  SAMPLE METER/RANGE/PPM                6.4/13/  19.      8.1/13/  24.      20.3/13/  61.       6.9/13/  21.
   NOX  BCKGRD METER/RANGE/PPM                 .6/ 2/   1.       .7/ 2/   1.        .8/ 2/   1.        .8/ 2/   1.

   DILUTION FACTOR                              48.90             30.18              12.27              48.34
   HC   CONCENTRATION PPM                        24.               33.                62.                22.
   CO   CONCENTRATION PPM                        95.              113.               141.                81.
   CO2  CONCENTRATION PCT                        .22               .39               1.03                .23
   NOX  CONCENTRATION PPM                       18.5              23.7               60.2               19.9

   HC   MASS GRAMS                              4.12              5.72              10.76               3.77
   CO   MASS GRAMS                             32.54             39.12              49.68              27.88
   CO2  MASS GRAMS                            1183.5            2111.9             5710.3             1222.3
   NOX  MASS GRAMS                             10.38             13.44              34.74              11.17
   FUEL KG (LB)                                .536 (   1.18)    .997 (   2.20)    2.725 (   6.01)     .554 (   1.22)
   KW HR (HP HR)                               1.06 (   1.42)    2.07 (   2.78)     6.90 (   9.25)     1.10 (   1.47)

   BSHC G/KW HR (G/HP HR)                      3.87 (   2.89)    2.76 (   2.06)     1.56 (   1.16)     3.43 (   2.56)
   BSCO G/KW HR (G/HP HR)                     30.63 (  22.84)   18.89 (  14.08)     7.21 (   5.37)    25.40 (  18.94)
   BSCO2 G/KW HR (G/HP HR)                  1114.17 ( 830.84) 1019.55 ( 760.28)   828.08 ( 617.50)  1113.51 ( 830.35)
   BSNOX G/KW HR (G/HP HR)                     9.77 (   7.29)    6.49 (   4.84)     5.04 (   3.76)    10.17 (   7.59)
   BSFC KG/KW HR (LB/HP HR)                    .504 (   .829)    .481 (   .791)     .395 (   .650)     .504 (   .829)

TOTAL TEST RESULTS 4 BAGS                            PARTICULATE DATA, TOTAL FOR 4 BAGS

   TOTAL KW HR (HP HR)          11.13 ( 14.92)           90MM FILTER
    BSHC    G/KW HR (G/HP HR)    2.19 (  1.63)               SAMPLE FLOW      SCM(SCF)                    1.238 ( 43.74)
    BSCO    G/KW HR (G/HP HR)   13.41 ( 10.00)               MULTIPLIER FOR   G/TEST                       .957
    BSCO2   G/KW HR (G/HP HR)    919. (  685.)               MULTIPLIER FOR   G/KW HR (G/HP HR)            .0860 ( .0641)
    BSNOX   G/KW HR (G/HP HR)    6.27 (  4.67)               MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)        .1989 ( .0902)
    BSFC  KG/KW HR (LB/HP HR)    .432 (  .711)
                                                         20 X 20 FILTERS
                                                             SAMPLE FLOW      SCM(SCF)                    79.01 (2790.5)
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PART. G/KW-HR (G/HP-HR) .40 (.30)

TABLE E-3. ENGINE EMISSION RESULTS
HOT TRANSIENT

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                                                                                         PROJECT NO. 11-5044-001

ENGINE  NO. D20                               TEST NO.22-2H  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL            DATE 10/15/80
ENGINE  9.6 L(586. CID) I-6                   TIME                                  DIESEL   EM-465-F
CVS NO.  10                                     DYNO NO.  5                           BAG CART NO.  1

BAROMETER 733.81 MM HG(28.89 IN HG)           RELATIVE HUMIDITY ,  ENGINE-48. PCT ,  CVS-48. PCT
DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)         ABSOLUTE HUMIDITY 10.5 GM/KG( 73.8 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                        1                  2                  3                  4
  DESCRIPTION                                     NYNF               LANF               LAF                NYNF
  BLOWER DIF P MM. H2O(IN. H2O)               670.6 (26.4)       670.6 (26.4)       670.6 (26.4)       670.6 (26.4)
  BLOWER INLET P MM. H2O(IN. H2O)             520.7 (20.5)       520.7 (20.5)       520.7 (20.5)       520.7 (20.5)
  BLOWER INLET TEMP. DEG. C(DEG. F)            48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                             6187.              6264.              6370.              6201.
  TIME SECONDS                                   296.0              300.0              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)             292.0 (10314.)     295.9 (10450.)     300.9 (10627.)     292.9 (10345.)

  HC  SAMPLE METER/RANGE/PPM                   6.9/22/  35.       8.1/22/  41.      13.8/22/  69.       6.2/22/  31.
  HC  BCKGRD METER/RANGE/PPM                  11.7/ 1/  12.      10.7/ 1/  11.       8.8/ 1/   9.       7.9/ 1/   8.
  CO  SAMPLE METER/RANGE/PPM                  48.4/12/ 102.      54.0/12/ 116.      65.8/12/ 147.      82.5/13/  83.
  CO  BCKGRD METER/RANGE/PPM                    .2/12/   0.        .3/12/   1.        .4/12/   1.        .6/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                  16.6/ 3/  .26      25.3/ 3/  .41      60.6/ 3/ 1.07      16.6/ 3/  .26
  CO2 BCKGRD METER/RANGE/PCT                   2.7/ 3/  .04       2.4/ 3/  .04       2.5/ 3/  .04       3.2/ 3/  .05
  NOX SAMPLE METER/RANGE/PPM                   6.3/13/  19.       7.8/13/  23.      20.1/13/  60.       6.8/13/  21.
  NOX BCKGRD METER/RANGE/PPM                    .1/ 2/   0.        .2/ 2/   0.        .6/ 2/   1.        .5/ 2/   1.

  DILUTION FACTOR                                 48.23              31.29              12.23              48.62
  HC  CONCENTRATION PPM                           23.                30.                61.                23.
  CO  CONCENTRATION PPM                          100.               113.               141.                80.
  CO2 CONCENTRATION PCT                           .22                .38               1.04                .22
  NOX CONCENTRATION PPM                          18.9               23.3               59.6               20.0

  HC  MASS GRAMS                                 3.89               5.15              10.60               3.94
  CO  MASS GRAMS                                33.84              38.83              49.52              27.43
  CO2 MASS GRAMS                               1197.8             2044.6             5729.6             1160.9
  NOX MASS GRAMS                                10.54              13.18              34.33              11.22
  FUEL KG (LB)                              .533 (   1.18)     .965 (   2.13)    2.743 (   6.05)     .524 (   1.15)
  KW HR (HP HR)                             1.08 (   1.45)     2.09 (   2.80)     6.95 (   9.32)     1.08 (   1.45)

  BSHC G/KW HR (G/HP HR)                    3.60 (   2.68)     2.47 (   1.84)     1.53 (   1.14)     3.64 (   2.72)
  BSCO G/KW HR (G/HP HR)                   31.33 (  23.37)    18.59 (  13.86)     7.13 (   5.31)    25.40 (  18.94)
  BSCO2 G/KW HR (G/HP HR)                1109.14 ( 827.09)   978.71 ( 729.82)   824.54 ( 614.86)  1074.97 ( 801.61)
  BSNOX G/KW HR (G/HP HR)                   9.76 (   7.28)     6.31 (   4.70)     4.94 (   3.68)    10.39 (   7.75)
  BSFC KG/KW HR (LB/HP HR)                  .494 (   .812)     .462 (   .760)     .395 (   .649)     .485 (   .797)

TOTAL TEST RESULTS 4 BAGS                              PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)           11.20 ( 15.02)           90MM FILTER
   BSHC   G/KW HR (G/HP HR)      2.11 (  1.57)              SAMPLE FLOW       SCM(SCF)                 1.272 ( 44.92)
   BSCO   G/KW HR (G/HP HR)     13.36 (  9.96)              MULTIPLIER FOR  G/TEST                      .929
   BSCO2  G/KW HR (G/HP HR)      905. (  675.)              MULTIPLIER FOR  G/KW HR (G/HP HR)          .0830 ( .0619)
   BSNOX  G/KW HR (G/HP HR)      6.19 (  4.61)              MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)      .1950 ( .0884)
   BSFC  KG/KW HR (LB/HP HR)     .426 (  .700)
PART. G/KW-HR (G/HP-HR) .34 (.25)                        20 X 20 FILTERS
                                                            SAMPLE FLOW     SCM(SCF)                   75.27 (2658.4)
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                              TABLE E-4.  ENGINE EMISSION RESULTS                                  PROJECT NO, 11-5044-001
                                               HOT TRANSIENT

ENGINE  NO.D20                                  TEST NO.22-3H  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL              DATE 10/15/80
ENGINE  9.6 L(586. CID) I-6                     TIME                                 DIESEL   EM-465-F
CVS NO.  10                                       DYNO NO.  5                          BAG CART NO.  1

BAROMETER 733.81 MM HG(28.89 IN HG)             RELATIVE HUMIDITY ,  ENGINE-48, PCT ,  CVS-50, PCT
DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)           ABSOLUTE HUMIDITY 10,5 GM/KG( 73,8 GRAINS/LB)      NOX HUMIDITY C,F, 1,0000

BAG RESULTS
  BAG NUMBER                                         1                 2                 3                 4
  DESCRIPTION                                      NYNF              LANF               LAF              NYNF
  BLOWER DIF P MM. H2O(IN. H2O)               645.2 (25.4)      645,2 (25,4)      645,2 (25,4)      645,2 (25,4)
  BLOWER INLET P MM. H2O(IN. H2O)             518.2 (20.4)      518,2 (20,4)      518,2 (20,4)      518,2 (20,4)
  BLOWER INLET TEMP. DEG. C(DEG. F)            48.9 (120,0)      48,9 (120,0)      48,9 (120,0)      48,9 (120,0)
  BLOWER REVOLUTIONS                               6182.             6264.             6371.             6201,
  TIME SECONDS                                     296.0             300,0             305,0             297,0
  TOTAL FLOW STD. CU. METRES(SCF)             293.3 (10360.)    297,2 (10497,)    302,3 (10676,)    294,2 (10392,)

  HC   SAMPLE MFTER/RANGE/PPM                 7.1/22/  36.      7,8/22/  39,     13,8/22/  69,      6,3/22/  32,
  HC   BCKGRD MFTER/RANGE/PPM                10.8/ 1/  11.      9,3/ 1/   9,      7,8/ 1/   8,      8,4/ 1/   8,
  CO   SAMPLE MFTER/RANGE/PPM                96.4/13/  98.     54,6/12/ 117,     65,4/12/ 146,     84,3/13/  85,
  CO   BCKGRD MFTER/RANGE/PPM                  .9/13/   1,       ,2/12/   0,       ,2/12/   0,       ,7/13/   1,
  CO2  SAMPLE MFTER/RANGE/PCT                16.3/ 3/  ,26     26,1/ 3/  ,43     60,9/ 3/ 1,08     16,4/ 3/  ,26
  CO2  BCKGRD MFTER/RANGE/PCT                 2.7/ 3/  ,04      3,0/ 3/  ,05      2,9/ 3/  ,04      3,0/ 3/  ,05
  NOX  SAMPLE MFTER/RANGE/PPM                 6.4/13/  19,      8,1/13/  24,     20,1/13/  60,      6,9/13/  21,
  NOX  BCKGRD MFTER/RANGE/PPM                 1.0/ 2/   1,       ,9/ 2/   1,       ,9/ 2/   1,       ,9/ 2/   1,

  DILUTION FACTOR                                  49.17             30,31             12,16             49,17
  HC   CONCENTRATION PPM                             25.               30,               62,               23,
  CO   CONCENTRATION PPM                             95.              114,              141,               82,
  CO2  CONCENTRATION PCT                             .22               ,38              1,04               ,22
  NOX  CONCENTRATION PPM                            18.3              23,3              59,4              19,8

  HC   MASS GRAMS                                   4.22              5,16             10,81              3,95
  CO   MASS GRAMS                                  32.48             39,55             49,46             28,19
  CO2  MASS GRAMS                                 1176.2            2081,3            5758,0            1164,4
  NOX  MASS GRAMS                                  10.26             13,26             34,33             11,13
  FUEL KG (LB)                             .531 (   1.17)    ,980 (   2,16)   2,751 (   6,06)    ,531 (   1,17)
  KW HR (HP HR)                            1.07 (   1.44)    2,09 (   2,80)    6,92 (   9,28)    1,12 (   1,51)

  BSHC G/KW HR (G/HP HR)                   3.94 (   2.94)    2,47 (   1,84)    1,56 (   1,16)    3,51 (   2,62)
  BSCO G/KW HR (G/HP HR)                  30.32 (  22.61)   18,93 (  14,12)    7,15 (   5,33)   25,07 (  18,70)
  BSCO2 G/KW HR (G/HP HR)               1098.15 ( 818.89)  996,28 ( 742,93)  831,80 ( 620,27) 1035,74 ( 772,35)
  BSNOX G/KW HR (G/HP HR)                  9.58 (   7.14)    6,35 (   4,73)    4,96 (   3,70)    9,90 (   7,38)
  BSFC KG/KW HR (LB/HP HR)                 .496 (   ,816)    ,469 (   ,771)    ,397 (   ,653)    ,472 (   ,777)

TOTAL TEST RESULTS 4 BAGS                                  PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)            11.21 ( 15.03)              90MM FILTER
   BSHC    G/KW HR (G/HP HR)      2.15 (  1.61)                  SAMPLE FLOW      SCM(SCF)                    1,131 ( 39,94)
   BSCO    G/KW HR (G/HP HR)     13.36 (  9.96)                  MULTIPLIER FOR   G/TEST                      1,050
   BSCO2   G/KW HR (G/HP HR)      908. (  677.)                  MULTIPLIER FOR   G/KW HR (G/HP HR)            ,0937 ( ,0699)
   BSNOX   G/KW HR (G/HP HR)      6.15 (  4.59)                  MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)        ,2190 ( ,0993)
   BSFC  KG/KW HR (LB/HP HR)      .428 (  .703)
PART. G/KW-HR (G/HP-HR) .40 (.30)                            20 X 20 FILTERS
                                                                SAMPLE FLOW     SCM(SCF)                    79,21 (2797,6)
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TABLE E-5. ENGINE EMISSION RESULTS
COLD TRANSIENT

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                                                                                  PROJECT NO. 11-5044-001

ENGINE  NO.D20                              TEST NO.22-1C  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL          DATE 10/17/80
ENGINE  9.6 L(586. CID) L-6                 TIME 09110                     DIESEL   EM-465-F
CVS NO.  10                                   DYNO NO.  5                  BAG CART NO.  1

BAROMETER 736.35 MM HG(28.99 IN HG)         RELATIVE HUMIDITY ,  ENGINE-58. PCT ,  CVS-57. PCT
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)       ABSOLUTE HUMIDITY 11.5 GM/KG( 80.6 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                    1                  2                  3                  4
   DESCRIPTION                                  NYNF               LANF               LAF                NYNF
   BLOWER DIF P MM. H2O(IN. H2O)          650.2 (25.6)       650.2 (25.6)       650.2 (25.6)       650.2 (25.6)
   BLOWER INLET P MM. H2O(IN. H2O)        518.2 (20.4)       518.2 (20.4)       518.2 (20.4)       518.2 (20.4)
   BLOWER INLET TEMP. DEG. C(DEG. F)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
   BLOWER REVOLUTIONS                        6180.              6263.              6370.              6202.
   TIME SECONDS                              295.9              299.9              305.0              297.0
   TOTAL FLOW STD. CU. METRES(SCF)        294.6 (10405.)     298.5 (10545.)     303.6 (10725.)     295.6 (10442.)

   HC  SAMPLE METER/RANGE/PPM              6.4/22/  32.       8.8/22/  44.      14.1/22/  70.       5.9/22/  29.
   HC  BCKGRD METER/RANGE/PPM              9.7/ 1/  10.       9.7/ 1/  10.       8.5/ 1/   9.       9.0/ 1/   9.
   CO  SAMPLE METER/RANGE/PPM             50.7/12/ 108.      53.7/12/ 115.      62.0/12/ 137.      83.0/13/  83.
   CO  BCKGRD METER/RANGE/PPM               .3/12/   1.        .3/12/   1.        .2/12/   0.        .5/13/   0.
   CO2 SAMPLE METER/RANGE/PCT             19.0/ 3/  .30      27.9/ 3/  .46      63.5/ 3/ 1.13      17.6/ 3/  .28
   CO2 BCKGRD METER/RANGE/PCT              3.4/ 3/  .05       3.5/ 3/  .05       3.5/ 3/  .05       3.6/ 3/  .06
   NOX SAMPLE METER/RANGE/PPM              7.7/13/  23.       8.9/13/  27.      22.7/13/  68.       8.7/13/  26.
   NOX BCKGRD METER/RANGE/PPM               .7/ 2/   1.        .8/ 2/   1.        .8/ 2/   1.       1.0/ 2/   1.

   DILUTION FACTOR                          42.08              28.27              11.62              45.86
   HC  CONCENTRATION PPM                    23.                35.                63.                21.
   CO  CONCENTRATION PPM                   104.               112.               131.                81.
   CO2 CONCENTRATION PCT                     .25                .41               1.08                .23
   NOX CONCENTRATION PPM                    22.4               25.9               67.4               25.2

   HC  MASS GRAMS                            3.85               5.95              10.96               3.50
   CO  MASS GRAMS                           35.85              38.77              46.35              27.81
   CO2 MASS GRAMS                         1369.5             2223.5             6026.8             1229.8
   NOX MASS GRAMS                           12.61              14.78              39.15              14.25
   FUEL KG (LB)                              .633 (   1.40)   1.047 (   2.31)   2.885 (   6.36)    .558 (   1.23)
   KW HR (HP HR)                            1.12 (   1.50)    2.10 (   2.81)    6.95 (   9.32)    1.13 (   1.52)

   BSHC G/KW HR (G/HP HR)                   3.45 (   2.57)    2.84 (   2.12)    1.58 (   1.18)    3.09 (   2.30)
   BSCO G/KW HR (G/HP HR)                  32.14 (  23.97)   18.48 (  13.78)    6.67 (   4.97)   24.55 (  18.30)
   BSCO2 G/KW HR (G/HP HR)               1227.83 ( 915.59) 1059.82 ( 790.31)  867.30 ( 646.75) 1085.40 ( 809.34)
   BSNOX G/KW HR (G/HP HR)                 11.31 (   8.43)    7.04 (   5.25)    5.63 (   4.20)   12.58 (   9.38)
   BSFC KG/KW HR (LB/HP HR)                 .568 (   .933)    .499 (   .820)    .415 (   .683)    .492 (   .809)

TOTAL TEST RESULTS 4 BAGS                       PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)           11.30 ( 15.15)       90MM FILTER
   BSHC   G/KW HR (G/HP HR)      2.15 (  1.60)          SAMPLE FLOW     SCM(SCF)                 1.214 ( 42.87)
   BSCO   G/KW HR (G/HP HR)     13.17 (  9.82)          MULTIPLIER FOR  G/TEST                    .982
   BSCO2  G/KW HR (G/HP HR)     961.  ( 716.)           MULTIPLIER FOR  G/KW HR (G/HP HR)         .0870 ( .0649)
   BSNOX  G/KW HR (G/HP HR)      7.15 (  5.33)          MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)     .1918 ( .0870)
   BSFC  KG/KW HR (LB/HP HR)     .454 (  .746)
 PART. G/KW-HR (G/HP-HR) .36 (.27)                   20 X 20 FILTERS
                                                        SAMPLE FLOW     SCM(SCF)                 80.75 (2852.2)
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TABLE E-6. ENGINE EMISSION RESULTS
C TRANS.

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                                                                                         PROJECT NO. 11-5044-001
ENGINE  NO.D20
ENGINE  MODEL   80 VOLVO DUALFUEL                  TEST NO.22-2C  RUN1
ENGINE  9.6 L(586. CID) L-6                        DATE 10/20/80
CVS NO.  10                                        TIME 11:05                        DIESEL    EM-465-F
                                                     DYNO NO.  5                        BAG CART NO.  1

BAROMETER 746.76 MM HG(29.40 IN HG)                RELATIVE HUMIDITY ,  ENGINE-69. PCT ,  CVS-41. PCT
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)              ABSOLUTE HUMIDITY 11.4 GM/KG( 79.9 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                         1                  2                  3                  4
  DESCRIPTION                                       NYNF               LANF               LAF                NYNF
  BLOWER DIF P MM. H2O(IN. H2O)                 678.2 (26.7)       678.2 (26.7)       678.2 (26.7)       678.2 (26.7)
  BLOWER INLET P MM. H2O(IN. H2O)               520.7 (20.5)       520.7 (20.5)       520.7 (20.5)       520.7 (20.5)
  BLOWER INLET TEMP. DEG. C(DEG. F)              48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                               6177.              6262.              6371.              6201.
  TIME SECONDS                                    295.8              299.9              305.0              296.9
  TOTAL FLOW STD. CU. METRES(SCF)               298.7 (10549.)     302.8 (10694.)     308.0 (10880.)     299.8 (10590.)

  HC  SAMPLE METER/RANGE/PPM                     7.3/22/  36.       9.7/22/  48.      14.7/22/  73.       6.7/22/  34.
  HC  BCKGRD METER/RANGE/PPM                    11.5/ 1/  12.      11.1/ 1/  11.       9.9/ 1/  10.      12.0/ 1/  12.
  CO  SAMPLE METER/RANGE/PPM                    52.5/12/ 112.      54.2/12/ 116.      66.1/12/ 148.      85.8/13/  86.
  CO  BCKGRD METER/RANGE/PPM                      .7/12/   1.        .7/12/   1.        .7/12/   1.       1.9/13/   2.
  CO2 SAMPLE METER/RANGE/PCT                    19.3/ 3/  .31      26.9/ 3/  .44      66.2/ 3/ 1.19      16.9/ 3/  .27
  CO2 BCKGRD METER/RANGE/PCT                     2.6/ 3/  .04       2.8/ 3/  .04       3.0/ 3/  .05       2.8/ 3/  .04
  NOX SAMPLE METER/RANGE/PPM                     7.8/13/  23.       9.1/13/  27.      24.3/13/  73.       9.0/13/  27.
  NOX BCKGRD METER/RANGE/PPM                      .5/ 2/   1.        .5/ 2/   1.       1.0/ 2/   1.        .7/ 2/   1.

  DILUTION FACTOR                                 41.31              29.32              11.09              47.64
  HC  CONCENTRATION PPM                           25.                38.                64.                22.
  CO  CONCENTRATION PPM                          109.               113.               142.                83.
  CO2 CONCENTRATION PCT                            .27                .40               1.15                .23
  NOX CONCENTRATION PPM                           22.9               26.9               71.9               26.2

  HC  MASS GRAMS                                   4.31               6.55              11.44               3.80
  CO  MASS GRAMS                                  37.82              39.74              50.82              29.03
  CO2 MASS GRAMS                                1482.3             2215.0             6461.6             1249.2
  NOX MASS GRAMS                                  13.07              15.57              42.36              15.05
  FUEL KG (LB)                                    .642 (   1.41)    1.040 (   2.29)    3.105 (   6.85)     .569 (   1.25)
  KW HR (HP HR)                                   1.16 (   1.56)     2.14 (   2.87)     6.97 (   9.34)     1.24 (   1.66)

  BSHC G/KW HR (G/HP HR)                          3.72 (   2.77)     3.06 (   2.28)     1.64 (   1.22)     3.06 (   2.29)
  BSCO G/KW HR (G/HP HR)                         32.62 (  24.32)    18.55 (  13.83)     7.30 (   5.44)    23.42 (  17.46)
  BSCO2 G/KW HR (G/HP HR)                      1278.22 ( 953.17)  1033.96 ( 771.02)   927.51 ( 691.65)  1007.98 ( 751.65)
  BSNOX G/KW HR (G/HP HR)                        11.27 (   8.41)     7.27 (   5.42)     6.08 (   4.53)    12.14 (   9.05)
  BSFC KG/KW HR (LB/HP HR)                        .553 (   .910)     .485 (   .798)     .446 (   .733)     .459 (   .754)
TOTAL TEST RESULTS 4 BAGS                             PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          11.51 ( 15.43)             90MM FILTER
   BSHC   G/KW HR (G/HP HR)     2.27 (  1.69)                  SAMPLE FLOW       SCM(SCF)                   1.239 ( 43.78)
   BSCO   G/KW HR (G/HP HR)    13.68 ( 10.20)                  MULTIPLIER FOR    G/TEST                      .976
   BSCO2  G/KW HR (G/HP HR)    991.  (  739.)                  MULTIPLIER FOR    G/KW HR (G/HP HR)           .0848 ( .0632)
   BSNOX  G/KW HR (G/HP HR)     7.48 (  5.58)                  MULTIPLIER FOR    G/KG FUEL (G/LB FUEL)       .1822 ( .0826)
   BSFC  KG/KW HR (LB/HP HR)    .465 (  .765)
                                                          20 X 20 FILTERS
  PART. G/KW-HR (G/HP-HR)  .34 (.25)                          SAMPLE FLOW     SCM(SCF)                   82.41 (2910.6)
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TABLE E-7. ENGINE EMISSION RESULTS
COLD TRANSIENT

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                                                                                         PROJECT NO. 11-5044-001

ENGINE  NO.D20                              TEST NO.22-2C  RUNR
ENGINE  MODEL   80 VOLVO DUAL FUEL          DATE 10/22/80
ENGINE  9.6 L(586. CID) L-6                 TIME 10148                       DIESEL   EM-465-F
CVS NO.  10                                   DYNO NO.  5                      BAG CART NO.  1

BAROMETER 742.44 MM HG(29.23 IN HG)         RELATIVE HUMIDITY ,  ENGINE-61. PCT ,  CVS-42. PCT
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)       ABSOLUTE HUMIDITY 10.5 GM/KG( 73.4 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                      1                  2                  3                  4
  DESCRIPTION                                   NYNF               LANF                LAF               NYNF
  BLOWER DIF P MM. H2O(IN. H2O)            652.8 (25.7)       652.8 (25.7)       652.8 (25.7)       652.8 (25.7)
  BLOWER INLET P MM. H2O(IN. H2O)          523.2 (20.6)       523.2 (20.6)       523.2 (20.6)       523.2 (20.6)
  BLOWER INLET TEMP. DEG. C(DEG. F)         48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                          6180.              6261.              6370.              6201.
  TIME SECONDS                               295.9              300.0              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)          297.1 (10495.)     301.0 (10633.)     306.3 (10818.)     298.1 (10531.)

  HC   SAMPLE METER/RANGE/PPM               6.6/22/  33.       9.1/22/  46.      15.0/22/  75.       6.9/22/  35.
  HC   BCKGRD METER/RANGE/PPM               9.2/ 1/   9.       8.8/ 1/   9.       7.3/ 1/   7.      11.3/ 1/  11.
  CO   SAMPLE METER/RANGE/PPM              52.5/12/ 112.      59.0/12/ 129.      67.0/12/ 151.      86.2/13/  87.
  CO   BCKGRD METER/RANGE/PPM                .2/12/   0.        .2/12/   0.        .3/12/   1.        .4/13/   0.
  CO2  SAMPLE METER/RANGE/PCT              18.8/ 3/  .30      26.9/ 3/  .44      61.9/ 3/ 1.10      17.4/ 3/  .28
  CO2  BCKGRD METER/RANGE/PCT               2.9/ 3/  .04       3.0/ 3/  .05       2.9/ 3/  .04       3.2/ 3/  .05
  NOX  SAMPLE METER/RANGE/PPM               7.6/13/  23.       9.6/13/  29.      23.2/13/  70.       8.7/13/  26.
  NOX  BCKGRD METER/RANGE/PPM                .4/ 2/   0.        .5/ 2/   1.        .7/ 2/   1.        .6/ 2/   1.

  DILUTION FACTOR                             42.46              29.26              11.93              46.25
  HC   CONCENTRATION PPM                       24.                37.                68.                24.
  CO   CONCENTRATION PPM                      110.               126.               145.                85.
  CO2  CONCENTRATION PCT                       .26                .40               1.06                .23
  NOX  CONCENTRATION PPM                      22.4               28.2               69.0               25.6

  HC   MASS GRAMS                             4.13               6.44              12.04               4.06
  CO   MASS GRAMS                            37.93              44.07              51.70              29.43
  CO2  MASS GRAMS                           1404.0             2185.8             5946.3             1255.0
  NOX  MASS GRAMS                            12.72              16.22              40.45              14.60
  FUEL KG (LB)                          .620 (    1.37)   1.028 (    2.27)   2.848 (    6.28)    .569 (    1.25)
  KW HR (HP HR)                         1.01 (    1.35)    2.09 (    2.80)    7.11 (    9.53)    1.19 (    1.59)

  BSHC G/KW HR (G/HP HR)                4.09 (    3.05)    3.08 (    2.30)    1.69 (    1.26)    3.42 (    2.55)
  BSCO G/KW HR (G/HP HR)               37.58 (   28.03)   21.09 (   15.73)    7.27 (    5.42)   24.81 (   18.50)
  BSCO2 G/KW HR (G/HP HR)            1391.24 (1037.45) 1046.28 (  780.21)  836.54 (  623.81) 1058.02 (  788.96)
  BSNOX G/KW HR (G/HP HR)              12.61 (    9.40)    7.77 (    5.79)    5.69 (    4.24)   12.31 (    9.18)
  BSFC KG/KW HR (LB/HP HR)              .615 (   1.010)    .492 (    .809)    .401 (    .659)    .480 (    .789)

TOTAL TEST RESULTS 4 BAGS                          PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          11.39 ( 15.28)          90MM FILTER
  BSHC   G/KW HR (G/HP HR)      2.34 (  1.75)             SAMPLE FLOW      SCM(SCF)                   1.238 ( 43.71)
  BSCO   G/KW HR (G/HP HR)     14.32 ( 10.68)             MULTIPLIER FOR   G/TEST                      .972
  BSCO2  G/KW HR (G/HP HR)      947. (  706.)             MULTIPLIER FOR   G/KW HR (G/HP HR)           .0853 ( .0636)
  BSNOX  G/KW HR (G/HP HR)      7.37 (  5.50)             MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)       .1918 ( .0870)
  BSFC   KG/KW HR (LB/HP HR)    .445 (  .731)
                                                        20 X 20 FILTERS
                                                           SAMPLE FLOW     SCM(SCF)                   81.80 (2889.2)
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PART. G/KW-HR (G/HP-HR) .35 (.26)

TABLE E-8. ENGINE EMISSION RESULTS COLD TRANSIENT

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                                                                                  PROJECT NO. 11-5044-001

ENGINE  NO.D20                                   TEST NO.22-1C  RUN
ENGINE  MODEL    80 VOLVO DUAL FUEL              DATE 10/29/80
ENGINE  9.6 L(586. CID) L-6                      TIME  2:47                            DIESEL   EM-465-F
CVS NO.  10                                        DYNO NO.  5                         BAG CART NO.  1

BAROMETER 749.55 MM HG(29.51 IN HG)              RELATIVE HUMIDITY ,  ENGINE-55. PCT ,  CVS-20. PCT
DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)            ABSOLUTE HUMIDITY  9.5 GM/KG( 66.8 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                             1                    2                    3                    4
  DESCRIPTION                                          NYNF                 LANF                  LAF                 NYNF
  BLOWER DIF P MM. H2O(IN. H2O)                   685.8 (27.0)         685.8 (27.0)         685.8 (27.0)         685.8 (27.0)
  BLOWER INLET P MM. H2O(IN. H2O)                 530.9 (20.9)         530.9 (20.9)         530.9 (20.9)         530.9 (20.9)
  BLOWER INLET TEMP. DEG. C(DEG. F)                48.9 (120.0)         48.9 (120.0)         48.9 (120.0)         48.9 (120.0)
  BLOWER REVOLUTIONS                                  6180.                6265.                6371.                6201.
  TIME SECONDS                                        295.9                300.0                305.1                296.9
  TOTAL FLOW STD. CU. METRES(SCF)                 300.0 (10597.)       304.2 (10743.)       309.3 (10925.)       301.1 (10633.)

  HC  SAMPLE METER/RANGE/PPM                      6.0/22/  30.         8.5/22/  42.        13.8/22/  69.         6.2/22/  31.
  HC  BCKGRD METER/RANGE/PPM                      9.4/ 1/   9.        10.0/ 1/  10.         9.2/ 1/   9.        11.0/ 1/  11.
  CO  SAMPLE METER/RANGE/PPM                     48.0/12/ 101.        50.8/12/ 108.        63.7/12/ 142.        82.3/13/  82.
  CO  BCKGRD METER/RANGE/PPM                       .9/12/   2.          .7/12/   1.          .6/12/   1.         1.8/13/   2.
  CO2 SAMPLE METER/RANGE/PCT                     18.4/ 3/  .29        26.1/ 3/  .43        63.3/ 3/ 1.13        17.0/ 3/  .27
  CO2 BCKGRD METER/RANGE/PCT                      2.9/ 3/  .04         2.5/ 3/  .04         3.1/ 3/  .05         3.0/ 3/  .05
  NOX SAMPLE METER/RANGE/PPM                      8.3/13/  25.        10.3/13/  31.        25.9/13/  78.         9.5/13/  28.
  NOX BCKGRD METER/RANGE/PPM                       .6/ 2/   1.          .6/ 2/   1.         1.2/ 2/   1.         1.2/ 2/   1.

  DILUTION FACTOR                                     43.57                30.34                11.66                47.46
  HC  CONCENTRATION PPM                               21.                  33.                  61.                  20.
  CO  CONCENTRATION PPM                               98.                 105.                 137.                  80.
  CO2 CONCENTRATION PCT                               .25                  .39                 1.09                  .23
  NOX CONCENTRATION PPM                               24.2                 30.2                 76.5                 27.2

  HC  MASS GRAMS                                      3.63                 5.76                10.84                 3.52
  CO  MASS GRAMS                                     34.29                37.21                49.18                28.02
  CO2 MASS GRAMS                                     1380.5               2171.6               6148.5               1246.9
  NOX MASS GRAMS                                     13.91                17.59                45.26                15.66
  FUEL KG (LB)                                     .587 (     1.30)    1.027 (     2.26)    2.957 (     6.52)     .566 (     1.25)
  KW HR (HP HR)                                    1.06 (     1.42)     2.15 (     2.88)     7.20 (     9.65)     1.14 (     1.53)

  BSHC G/KW HR (G/HP HR)                           3.42 (     2.55)     2.68 (     2.00)     1.51 (     1.12)     3.06 (     2.30)
  BSCO G/KW HR (G/HP HR)                          32.28 (    24.07)    17.30 (    12.90)     6.83 (     5.10)    24.54 (    18.30)
  BSCO2 G/KW HR (G/HP HR)                       1299.58 (   969.10)  1009.55 (   752.82)   854.35 (   637.09)  1091.91 (   814.24)
  BSNOX G/KW HR (G/HP HR)                         13.09 (     9.76)     8.18 (     6.10)     6.29 (     4.69)    13.72 (    10.23)
  BSFC KG/KW HR (LB/HP HR)                         .553 (     .909)     .477 (     .785)     .411 (     .675)     .495 (     .814)

TOTAL TEST RESULTS 4 BAGS                                 PARTICULATE DATA, TOTAL FOR 4 BAGS

 TOTAL KW HR (HP HR)          11.55 ( 15.49)                  90MM FILTER
  BSHC   G/KW HR (G/HP HR)     2.06 (  1.53)                      SAMPLE FLOW     SCM(SCF)                 1.298 ( 45.84)
  BSCO   G/KW HR (G/HP HR)    12.87 (  9.60)                      MULTIPLIER FOR  G/TEST                    .936
  BSCO2  G/KW HR (G/HP HR)    948.  (  707.)                      MULTIPLIER FOR  G/KW HR (G/HP HR)         .0810 ( .0604)
  BSNOX  G/KW HR (G/HP HR)     8.00 (  5.97)                      MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)     .1822 ( .0826)
  BSFC  KG/KW HR (LB/HP HR)    .445 (  .731)
                                                              20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .32 (.24)                               SAMPLE FLOW     SCM(SCF)                 84.33 (2978.5)
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TABLE E-9. ENGINE EMISSION RESULTS COLD TRANSIENT

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                                                                                     PROJECT NO, 11-5044-001

ENGINE  NO.D20                                TEST NO,22-2C  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL            DATE 10/30/80
ENGINE  9.6 L(586. CID) L-6                   TIME 10159                                  DIESEL   EM-465-F
CVS NO,  10                                     DYNO NO,  5                               BAG CART NO,  1

BAROMETER 753.36 MM HG(29.66 IN HG)           RELATIVE HUMIDITY ,  ENGINE=61, PCT ,  CVS=24, PCT
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)         ABSOLUTE HUMIDITY 10,3 GM/KG( 72,3 GRAINS/LB)       NOX HUMIDITY C,F, 1,0000

BAG RESULTS
  BAG NUMBER                                        1                   2                   3                   4
  DESCRIPTION                                     NYNF                LANF                 LAF                NYNF
  BLOWER DIF P MM, H2O(IN, H2O)            685.8 (27,0)        685,8 (27,0)        685,8 (27,0)        685,8 (27,0)
  BLOWER INLET P MM, H2O(IN, H2O)          530,9 (20,9)        530,9 (20,9)        530,9 (20,9)        530,9 (20,9)
  BLOWER INLET TEMP. DEG. C(DEG. F)         48.9 (120,0)        48,9 (120,0)        48,9 (120,0)        48,9 (120,0)
  BLOWER REVOLUTIONS                            6181,               6264,               6370,               6202,
  TIME SECONDS                                  296.0               299,9               305,0               297,0
  TOTAL FLOW STD. CU. METRES(SCF)         301.6 (10652,)      305,6 (10795,)      310,8 (10978,)      302,6 (10689,)

  HC   SAMPLE METER/RANGE/PPM               6.8/22/  34,        9,5/22/  48,       16,0/22/  80,        7,0/22/  35,
  HC   BCKGRD METER/RANGE/PPM               8,7/ 1/   9,        8,5/ 1/   9,       10,0/ 1/  10,       10,0/ 1/  10,
  CO   SAMPLE METER/RANGE/PPM              99,2/13/ 101,       50,8/12/ 108,       62,7/12/ 139,       81,8/13/  82,
  CO   BCKGRD METER/RANGE/PPM               1,5/13/   1,        ,7/12/    1,        ,7/12/    1,        1,5/13/   1,
  CO2  SAMPLE METER/RANGE/PCT              18,6/ 3/  ,30       26,9/ 3/  ,44       61,6/ 3/ 1,09       16,3/ 3/  ,26
  CO2  BCKGRD METER/RANGE/PCT               2,3/ 3/  ,04        2,8/ 3/  ,04        2,5/ 3/  ,04        2,2/ 3/  ,03
  NOX  SAMPLE METER/RANGE/PPM               8,3/13/  25,        9,9/13/  30,       25,0/13/  75,        9,3/13/  28,
  NOX  BCKGRD METER/RANGE/PPM               1,7/ 2/   2,        1,7/ 2/   2,        1,5/ 2/   2,        1,5/ 2/   2,

  DILUTION FACTOR                              43.04               29,37               12,00               49,45
  HC   CONCENTRATION PPM                       26,                 39,                 71,                 25,
  CO   CONCENTRATION PPM                       98.                 105,                134,                80,
  CO2  CONCENTRATION PCT                       .26                 ,40                 1,06                ,23
  NOX  CONCENTRATION PPM                       23.2                28,0                73,7                26,3

  HC   MASS GRAMS                              4,45                6,93                12,66               4,43
  CO   MASS GRAMS                              34.51               37,34               48,38               28,04
  CO2  MASS GRAMS                              1456.2              2235,9              6032,5              1255,3
  NOX  MASS GRAMS                              13.36               16,39               43,82               15,23
  FUEL KG (LB)                              ,633 (   1,40)     1,052 (   2,32)     2,893 (   6,38)      ,569 (   1,25)
  KW HR (HP HR)                             1.02 (   1,37)      2,06 (   2,77)      6,93 (   9,29)      1,16 (   1,56)

  BSHC G/KW HR (G/HP HR)                    4,37 (   3,26)      3,36 (   2,51)      1,83 (   1,36)      3,82 (   2,85)
  BSCO G/KW HR (G/HP HR)                   33,90 (  25,28)     18,10 (  13,50)      6,98 (   5,20)     24,18 (  18,03)
  BSCO2 G/KW HR (G/HP HR)                1430,45 (1066,69)   1084,05 ( 808,38)    870,34 ( 649,02)   1082,52 ( 807,24)
  BSNOX G/KW HR (G/HP HR)                  13.12 (   9,78)      7,95 (   5,93)      6,32 (   4,71)     13,14 (   9,79)
  BSFC KG/KW HR (LB/HP HR)                  .622 (  1,022)      ,510 (   ,839)      ,417 (   ,686)      ,491 (   ,807)

TOTAL TEST RESULTS 4 BAGS                            PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          11,17 ( 14,98)          90MM FILTER
  BSHC    G/KW HR (G/HP HR)     2,55 (  1,90)              SAMPLE FLOW      SCM(SCF)                     1,321 ( 46,66)
  BSCO    G/KW HR (G/HP HR)    13,27 (  9,90)              MULTIPLIER FOR   G/TEST                        ,924
  BSCO2   G/KW HR (G/HP HR)    983,  ( 733,)               MULTIPLIER FOR   G/KW HR (G/HP HR)             ,0827 ( ,0617)
  BSNOX   G/KW HR (G/HP HR)     7,95 (  5,93)              MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)         ,1795 ( ,0814)
  BSFC   KG/KW HR (LB/HP HR)    ,461 (  ,757)
                                                        20 X 20 FILTERS
                                                           SAMPLE FLOW     SCM(SCF)                      84,25 (2975,7)
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PART. G/KW-HR (G/HP-HR) .34 (.25)

TABLE E-10. ENGINE EMISSION RESULTS

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                                                      C-TRANS.
                                                                                           PROJECT NO. 11-5044-00
ENGINE  NO.D20
ENGINE  MODEL   80 VOLVO DUALFUEL                 TEST NO.22-1C  RUN
ENGINE  9.6 L(586. CID) L-6                       DATE 11/19/90
CVS NO.  10                                       TIME 11:03
                                                   DYNO NO.  5                        DIESEL   EM-465-F
                                                                                       BAG CART NO.  1
BAROMETER 751.08 MM HG(29.57 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)             RELATIVE HUMIDITY ,  ENGINE-49. PCT ,  CVS-17. PCT
                                                  ABSOLUTE HUMIDITY  9.2 GM/KG( 64.1 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000
BAG RESULTS
   BAG NUMBER                                          1                   2                   3                   4
   DESCRIPTION                                       NYNF                LANF                 LAF                NYNF
   BLOWER DIF P MM. H2O(IN. H2O)                 688.3 (27.1)        688.3 (27.1)        688.3 (27.1)        688.3 (27.1)
   BLOWER INLET P MM. H2O(IN. H2O)               530.9 (20.9)        530.9 (20.9)        530.9 (20.9)        530.9 (20.9)
   BLOWER INLET TEMP. DEG. C(DEG. F)              48.9 (120.0)        48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
   BLOWER REVOLUTIONS                               6183.               6267.               6372.               6202.
   TIME SECONDS                                     296.0               300.0               305.0               296.9
   TOTAL FLOW STD. CU. METRES(SCF)               300.4 (10608.)      304.4 (10753.)      309.5 (10933.)      301.3 (10641.)

   HC  SAMPLE METER/RANGE/PPM                     7.2/22/  36.        9.2/22/  46.       15.2/22/  76.        6.5/22/  32.
   HC  BCKGRD METER/RANGE/PPM                     9.8/ 1/  10.        8.5/ 1/   9.        8.6/ 1/   9.        8.2/ 1/   8.
   CO  SAMPLE METER/RANGE/PPM                    57.7/12/ 125.       48.3/12/ 102.       50.6/12/ 107.       90.7/13/  91.
   CO  BCKGRD METER/RANGE/PPM                      .7/12/   1.         .7/12/   1.         .8/12/   1.        1.4/13/   1.
   CO2 SAMPLE METER/RANGE/PCT                    17.7/ 3/  .28       26.0/ 3/  .43       62.7/ 3/ 1.12       17.3/ 3/  .28
   CO2 BCKGRD METER/RANGE/PCT                     3.0/ 3/  .05        2.5/ 3/  .04        2.7/ 3/  .04        2.6/ 3/  .04
   NOX SAMPLE METER/RANGE/PPM                     5.3/13/  16.        7.8/13/  23.       25.0/13/  75.        8.6/13/  26.
   NOX BCKGRD METER/RANGE/PPM                      .3/ 2/   0.         .3/ 2/   0.         .4/ 2/   0.         .4/ 2/   0.

   DILUTION FACTOR                                 44.84               30.48               11.81               46.47
   HC  CONCENTRATION PPM                           27.                 38.                 68.                 24.
   CO  CONCENTRATION PPM                          123.                 99.                103.                 89.
   CO2 CONCENTRATION PCT                            .24                 .39                1.08                 .24
   NOX CONCENTRATION PPM                           15.6                23.2                74.6                25.4

   HC  MASS GRAMS                                   4.62                6.61               12.12                4.21
   CO  MASS GRAMS                                  42.97               35.13               37.18               31.27
   CO2 MASS GRAMS                                1308.7              2163.7              6116.5              1308.9
   NOX MASS GRAMS                                   8.97               13.50               44.15               14.62
   FUEL KG (LB)                                    .616 (   1.36)     1.023 (   2.26)     2.941 (   6.48)      .600 (   1.32)
   KW HR (HP HR)                                   1.10 (   1.48)      2.15 (   2.88)      7.40 (   9.93)      1.13 (   1.51)

   BSHC G/KW HR (G/HP HR)                          4.20 (   3.13)      3.08 (   2.30)      1.64 (   1.22)      3.74 (   2.79)
   BSCO G/KW HR (G/HP HR)                         39.07 (  29.13)     16.37 (  12.21)      5.02 (   3.75)     27.74 (  20.69)
   BSCO2 G/KW HR (G/HP HR)                      1189.70 ( 887.16)   1008.25 ( 751.85)    826.23 ( 616.12)   1161.27 ( 865.96)
   BSNOX G/KW HR (G/HP HR)                         8.16 (   6.08)      6.29 (   4.69)      5.96 (   4.45)     12.97 (   9.67)
   BSFC KG/KW HR (LB/HP HR)                        .560 (   .920)      .477 (   .784)      .397 (   .653)      .532 (   .875)
TOTAL TEST RESULTS 4 BAGS                                   PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)             11.78 ( 15.79)               90MM FILTER
   BSHC    G/KW HR (G/HP HR)       2.34 (  1.75)                   SAMPLE FLOW      SCM(SCF)                     1.303 ( 46.03)
   BSCO    G/KW HR (G/HP HR)      12.45 (  9.28)                   MULTIPLIER FOR   G/TEST                        .933
   BSCO2   G/KW HR (G/HP HR)      925.  ( 690.)                    MULTIPLIER FOR   G/KW HR (G/HP HR)             .0792 ( .0591)
   BSNOX   G/KW HR (G/HP HR)       6.90 (  5.14)                   MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)         .1801 ( .0817)
   BSFC   KG/KW HR (LB/HP HR)      .440 (  .723)
                                                               20 X 20 FILTERS
  PART. G/KW-HR (G/HP-HR)  .30 (.22)                               SAMPLE FLOW      SCM(SCF)                    82.64 (2918.9)
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TABLE E-11. ENGINE EMISSION RESULTS HOT TRANSIENT

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                                                                                        PROJECT NO. 11-5044-001

ENGINE  NO.D20                            TEST NO.22-1H  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL        DATE 10/17/80
ENGINE  9.6 L(586. CID) L-6               TIME 0915U                       DIESEL   EM-465-F
CVS NO.  10                                 DYNO NO.  5                      BAG CART NO.  1

BAROMETER 736.35 MM HG(28.99 IN HG)       RELATIVE HUMIDITY ,  ENGINE-58. PCT ,  CVS-60. PCT
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)     ABSOLUTE HUMIDITY 11.5 GM/KG( 80.6 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                     1                   2                   3                   4
  DESCRIPTION                                   NYNF                LANF                LAF                 NYNF
  BLOWER DIF P MM. H2O(IN. H2O)           650.2 (25.6)        650.2 (25.6)        650.2 (25.6)        650.2 (25.6)
  BLOWER INLET P MM. H2O(IN. H2O)         518.2 (20.4)        518.2 (20.4)        518.2 (20.4)        518.2 (20.4)
  BLOWER INLET TEMP. DEG. C(DEG. F)        48.9 (120.0)        48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
  BLOWER REVOLUTIONS                          6182.               6263.               6372.               6203.
  TIME SECONDS                                296.0               300.0               305.0               297.0
  TOTAL FLOW STD. CU. METRES(SCF)        294.7 (10407.)      298.5 (10544.)      303.7 (10727.)      295.7 (10443.)

  HC   SAMPLE METER/RANGE/PPM             6.7/22/  33.        8.5/22/  43.       14.2/22/  71.        6.4/22/  32.
  HC   BCKGRD METER/RANGE/PPM            10.7/ 1/  11.       10.2/ 1/  10.        9.2/ 1/   9.        9.0/ 1/   9.
  CO   SAMPLE METER/RANGE/PPM            91.2/13/  92.       50.5/12/ 107.       64.5/12/ 144.       81.9/13/  82.
  CO   BCKGRD METER/RANGE/PPM              .4/13/   0.         .1/12/   0.         .2/12/   0.         .3/13/   0.
  CO2 SAMPLE METER/RANGE/PCT             16.8/ 3/  .27       26.0/ 3/  .43       61.8/ 3/ 1.10       16.8/ 3/  .27
  CO2 BCKGRD METER/RANGE/PCT              3.6/ 3/  .06        3.5/ 3/  .05        3.1/ 3/  .05        3.2/ 3/  .05
  NOX SAMPLE METER/RANGE/PPM              7.7/13/  23.        8.9/13/  27.       22.2/13/  67.        8.5/13/  26.
  NOX BCKGRD METER/RANGE/PPM               .8/ 2/   1.         .7/ 2/   1.         .8/ 2/   1.         .7/ 2/   1.

  DILUTION FACTOR                             47.84               30.47               11.97               48.04
  HC  CONCENTRATION PPM                        23.                 33.                 63.                 23.
  CO  CONCENTRATION PPM                        90.                104.                138.                 80.
  CO2 CONCENTRATION PCT                        .21                 .37                1.06                 .22
  NOX CONCENTRATION PPM                       22.3                26.0                66.0                24.9

  HC  MASS GRAMS                              3.88                5.66               10.97                3.95
  CO  MASS GRAMS                             30.77               36.16               48.67               27.45
  CO2 MASS GRAMS                            1153.3              2040.1              5869.7              1190.0
  NOX MASS GRAMS                             12.56               14.83               38.33               14.09
  FUEL KG (LB)                           .509 (   1.12)   .961 (   2.12)   2.807 (   6.19)    .542 (   1.20)
  KW HR (HP HR)                          1.13 (   1.52)   2.12 (   2.84)    7.01 (   9.40)    1.13 (   1.52)

  BSHC G/KW HR (G/HP HR)                 3.43 (   2.56)   2.67 (   1.99)    1.56 (   1.17)    3.49 (   2.60)
  BSCO G/KW HR (G/HP HR)                27.16 (  20.25)  17.09 (  12.75)    6.94 (   5.18)   24.22 (  18.06)
  BSCO2 G/KW HR (G/HP HR)             1017.82 ( 758.99) 964.28 ( 719.06)  837.24 ( 624.33) 1050.23 ( 783.16)
  BSNOX G/KW HR (G/HP HR)               11.08 (   8.26)   7.01 (   5.23)    5.47 (   4.08)   12.44 (   9.27)
  BSFC KG/KW HR (LB/HP HR)              .449 (   .738)   .454 (   .747)    .400 (   .658)    .479 (   .787)

TOTAL TEST RESULTS 4 BAGS                       PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)       11.39 ( 15.28)        90MM FILTER
   BSHC   G/KW HR (G/HP HR)  2.15 (  1.60)          SAMPLE FLOW     SCM(SCF)                 1.249 ( 44.12)
   BSCO   G/KW HR (G/HP HR) 12.56 (  9.36)          MULTIPLIER FOR  G/TEST                    .955
   BSCO2  G/KW HR (G/HP HR)  900. (  671.)          MULTIPLIER FOR  G/KW HR (G/HP HR)         .0838 ( .0625)
   BSNOX  G/KW HR (G/HP HR)  7.01 (  5.22)          MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)     .1981 ( .0899)
   BSFC  KG/KW HR (LB/HP HR) .423 (  .695)
                                                  20 X 20 FILTERS
 PART. G/KW-HR (G/HP-HR) .36 (.27)                  SAMPLE FLOW     SCM(SCF)                 80.62 (2847.6)
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TABLE E-12. ENGINE EMISSION RESULTS

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                                                   HOT TRANSIENT                                  PROJECT NO. 11-5044-001

ENGINE  NO. D20                                  TEST NO.22-2H  RUN
ENGINE  MODEL  80 VOLVO DUAL FUEL                DATE 10/20/80
ENGINE  9.6 L(586. CID) L-6                      TIME                                   DIESEL   EM-465-F
CVS NO.  10                                        DYNO NO.  5                             BAG CART NO.  1

BAROMETER 746.76 MM HG(29.40 IN HG)              RELATIVE HUMIDITY ,  ENGINE=43. PCT ,  CVS=36. PCT
DRY BULB TEMP. 28.9 DEG C(84.0 DEG F)            ABSOLUTE HUMIDITY 10.8 GM/KG( 75.5 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                          1                  2                  3                  4
   DESCRIPTION                                       NYNF               LANF                LAF               NYNF
   BLOWER DIF P MM. H2O(IN. H2O)                 678.2 (26.7)       678.2 (26.7)       678.2 (26.7)       678.2 (26.7)
   BLOWER INLET P MM. H2O(IN. H2O)               520.7 (20.5)       520.7 (20.5)       520.7 (20.5)       520.7 (20.5)
   BLOWER INLET TEMP. DEG. C(DEG. F)              48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
   BLOWER REVOLUTIONS                                6180.              6263.              6371.              6202.
   TIME SECONDS                                     296.0              299.9              305.0              297.0
   TOTAL FLOW STD. CU. METRES(SCF)              298.9 (10557.)     302.9 (10698.)     308.1 (10883.)     299.9 (10594.)

   HC  SAMPLE METER/RANGE/PPM                    7.1/22/  35.       8.5/22/  42.      13.3/22/  67.       6.6/22/  33.
   HC  BCKGRD METER/RANGE/PPM                   10.4/ 1/  10.       9.8/ 1/  10.       8.7/ 1/   9.       8.2/ 1/   8.
   CO  SAMPLE METER/RANGE/PPM                   91.8/13/  93.      50.6/12/ 107.      68.9/12/ 156.      82.0/13/  82.
   CO  BCKGRD METER/RANGE/PPM                    1.5/13/   1.        .9/12/   2.        .9/12/   2.       1.5/13/   1.
   CO2 SAMPLE METER/RANGE/PCT                   15.9/ 3/  .25      24.8/ 3/  .40      64.9/ 3/ 1.16      16.7/ 3/  .27
   CO2 BCKGRD METER/RANGE/PCT                    2.8/ 3/  .04       2.9/ 3/  .04       3.2/ 3/  .05       3.2/ 3/  .05
   NOX SAMPLE METER/RANGE/PPM                    6.7/13/  20.       8.1/13/  24.      21.6/13/  65.       7.7/13/  23.
   NOX BCKGRD METER/RANGE/PPM                     .7/ 2/   1.        .7/ 2/   1.        .8/ 2/   1.        .7/ 2/   1.

   DILUTION FACTOR                                 50.49              31.99              11.33              48.30
   HC  CONCENTRATION PPM                             25.                33.                59.                25.
   CO  CONCENTRATION PPM                             90.               104.               149.                79.
   CO2 CONCENTRATION PCT                             .21                .36               1.12                .22
   NOX CONCENTRATION PPM                            19.3               23.7               64.0               22.4

   HC  MASS GRAMS                                   4.32               5.72              10.42               4.31
   CO  MASS GRAMS                                  31.37              36.58              53.55              27.75
   CO2 MASS GRAMS                                 1153.8             2003.3             6298.8             1198.0
   NOX MASS GRAMS                                  11.04              13.71              37.72              12.88
   FUEL KG (LB)                                  .539 (   1.19)    .942 (   2.08)   3.034 (   6.69)    .543 (   1.20)
   KW HR (HP HR)                                 1.05 (   1.41)    1.98 (   2.66)    7.00 (   9.39)    1.10 (   1.47)

   BSHC G/KW HR (G/HP HR)                        4.10 (   3.06)    2.89 (   2.15)    1.49 (   1.11)    3.93 (   2.93)
   BSCO G/KW HR (G/HP HR)                       29.78 (  22.20)   18.45 (  13.76)    7.65 (   5.70)   25.28 (  18.85)
   BSCO2 G/KW HR (G/HP HR)                    1095.27 ( 816.74) 1010.29 ( 753.37)  899.57 ( 670.81) 1091.44 ( 813.89)
   BSNOX G/KW HR (G/HP HR)                      10.48 (   7.81)    6.92 (   5.16)    5.39 (   4.02)   11.73 (   8.75)
   BSFC KG/KW HR (LB/HP HR)                      .512 (   .841)    .475 (   .781)    .433 (   .712)    .495 (   .813)

TOTAL TEST RESULTS 4 BAGS                           PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)         11.14 ( 14.93)          90MM FILTER
   BSHC   G/KW HR (G/HP HR)    2.23 (  1.66)               SAMPLE FLOW      SCM(SCF)                   1.276 ( 45.08)
   BSCO   G/KW HR (G/HP HR)   13.40 (  9.99)               MULTIPLIER FOR  G/TEST                      .948
   BSCO2  G/KW HR (G/HP HR)   957. (  713.)                MULTIPLIER FOR  G/KW HR (G/HP HR)           .0851 ( .0635)
   BSNOX  G/KW HR (G/HP HR)    6.77 (  5.05)               MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)       .1874 ( .0850)
   BSFC  KG/KW HR (LB/HP HR)   .454 (  .747)
                                                        20 X 20 FILTERS
                                                           SAMPLE FLOW     SCM(SCF)                    82.66 (2919.4)
```

PART. G/KW-HR (G/HP-HR) .35 (.26)

TABLE E-13. ENGINE EMISSION RESULTS HOT TRANSIENT

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                                                                               PROJECT NO, 11-5044-001

ENGINE  NO.D20                           TEST NO.22-2H  RUNR
ENGINE  MODEL   80 VOLVO DUAL FUEL       DATE 10/22/80
ENGINE  9.6 L(586. CID) L-6              TIME 11132                       DIESEL   FM-465-F
CVS NO.  10                                DYNO NO.  5                      BAG CART NO.  1

BAROMETER 742,44 MM HG(29,23 IN HG)      RELATIVE HUMIDITY ,  ENGINE=42. PCT ,  CVS=40. PCT
DRY BULB TEMP. 28.9 DEG C(84.0 DEG F)    ABSOLUTE HUMIDITY 10,7 GM/KG( 75,1 GRAINS/LB)     NOX HUMIDITY C,F. 1,0000

BAG RESULTS
   BAG NUMBER                                  1                  2                  3                  4
   DESCRIPTION                               NYNF               LANF                LAF               NYNF
   BLOWER DIF P MM, H2O(IN, H2O)         650,2 (25,6)       650,2 (25,6)       650,2 (25,6)       650,2 (25,6)
   BLOWER INLET P MM, H2O(IN, H2O)       520,7 (20,5)       520,7 (20,5)       520,7 (20,5)       520,7 (20,5)
   BLOWER INLET TEMP. DEG. C(DEG. F)      48.9 (120,0)       48,9 (120,0)       48,9 (120,0)       48,9 (120,0)
   BLOWER REVOLUTIONS                         6182.              6264.              6371.              6202.
   TIME SECONDS                               296.0              300,0              305,0              297,0
   TOTAL FLOW STD. CU. METRES(SCF)      297.3 (10499.)     301,2 (10638,)     306,3 (10820,)     298,2 (10533,)

   HC  SAMPLE METER/RANGE/PPM            7.4/22/  37.       8,8/22/  44.      14,7/22/  73.       7,3/22/  36.
   HC  BCKGRD METER/RANGE/PPM           10.3/ 1/  10.       8,8/ 1/   9.       8,2/ 1/   8.       7,6/ 1/   8.
   CO  SAMPLE METER/RANGE/PPM           92.0/13/  93.      52,3/12/ 112.      66,7/12/ 150.      82,2/13/  82.
   CO  BCKGRD METER/RANGE/PPM            1.0/13/   1.        ,5/12/   1.        ,6/12/   1.       1,2/13/   1.
   CO2 SAMPLE METER/RANGE/PCT           16.2/ 3/  .26      24,8/ 3/  ,40      61,6/ 3/ 1,09      16,2/ 3/  ,26
   CO2 BCKGRD METER/RANGE/PCT            2.7/ 3/  .04       2,9/ 3/  ,04       2,7/ 3/  ,04       2,6/ 3/  ,04
   NOX SAMPLE METER/RANGE/PPM            8.0/13/  24.       9,2/13/  28.      22,6/13/  68.       8,7/13/  26.
   NOX BCKGRD METER/RANGE/PPM             .4/ 2/   0.        ,5/ 2/   1.        ,5/ 2/   1.        ,5/ 2/   1.

   DILUTION FACTOR                           49,52              31,95              12,00              49,73
   HC  CONCENTRATION PPM                       27,                35.                66.                29.
   CO  CONCENTRATION PPM                       91.               108.               144.                80.
   CO2 CONCENTRATION PCT                       .22                .36               1,06                ,22
   NOX CONCENTRATION PPM                      23.5               27.0               67,2               25,7

   HC  MASS GRAMS                             4.65               6,15              11,64               4,97
   CO  MASS GRAMS                            31.37              38,03              51,28              27,72
   CO2 MASS GRAMS                           1182.9             1992,0             5929,8             1195,0
   NOX MASS GRAMS                            13,39              15,57              39,41              14,66
   FUEL KG (LB)                          .518 (    1.14)   ,938 (    2,07)  2,837 (    6,25)   ,542 (    1,20)
   KW HR (HP HR)                         1.11 (    1.48)   2,10 (    2,81)   7,13 (    9,56)   1,16 (    1,56)

   BSHC G/KW HR (G/HP HR)                4,20 (    3,13)   2,93 (    2,19)   1,63 (    1,22)   4,29 (    3,20)
   BSCO G/KW HR (G/HP HR)               28,35 (   21.14)  18,13 (   13,52)   7,20 (    5,37)  23,90 (   17,82)
   BSCO2 G/KW HR (G/HP HR)            1069,07 (  797,21) 949,52 (  708,06) 832,14 (  620,53) 1030,50 (  768,45)
   BSNOX G/KW HR (G/HP HR)              12.10 (    9,02)   7,42 (    5,53)   5,53 (    4,12)  12,64 (    9,42)
   BSFC KG/KW HR (LB/HP HR)              .468 (    ,769)   ,447 (    ,735)   ,398 (    ,655)   ,468 (    ,769)

TOTAL TEST RESULTS 4 BAGS                          PARTICULATE DATA, TOTAL FOR 4 BAGS

   TOTAL KW HR (HP HR)           11,49 ( 15,41)        90MM FILTER
    BSHC    G/KW HR (G/HP HR)     2,39 (  1,78)            SAMPLE FLOW      SCM(SCF)                1,255 ( 44,33)
    BSCO    G/KW HR (G/HP HR)    12,92 (  9,63)            MULTIPLIER FOR   G/TEST                   ,958
    BSCO2   G/KW HR (G/HP HR)     896. (  668,)            MULTIPLIER FOR   G/KW HR (G/HP HR)        ,0834 ( ,0622)
    BSNOX   G/KW HR (G/HP HR)     7,23 (  5,39)            MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)    ,1982 ( ,0899)
    BSFC   KG/KW HR (LB/HP HR)    .421 (  ,692)
                                                       20 X 20 FILTERS
                                                           SAMPLE FLOW      SCM(SCF)                81,46 (2877,0)
```

PART. G/KW-HR (G.HP-HR) .36 (.27)

TABLE E-14. ENGINE EMISSION RESULTS

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                                HOT TRANSIENT                                        PROJECT NO, 11-5044-001

ENGINE  NO.020                              TEST NO,22-1H  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL          DATE 10/29/80
ENGINE  9.6 L(586. CID) L-6                 TIME                                 DIESEL   EM-465-F
CVS NO.  10                                   DYNO NO.  5                          BAG CART NO.  1

BAROMETER 749,55 MM HG(29,51 IN HG)         RELATIVE HUMIDITY ,  ENGINE-43, PCT ,  CVS-20, PCT
DRY BULB TEMP. 27.2 DEG C(81.0 DEG F)       ABSOLUTE HUMIDITY  9,9 GM/KG( 69,0 GRAINS/LB)      NOX HUMIDITY C,F, 1,0000

BAG RESULTS
   BAG NUMBER                                    1                    2                    3                    4
   DESCRIPTION                                  NYNF                 LANF                 LAF                  NYNF
   BLOWER DIF P MM. H2O(IN. H2O)           685,8 (27,0)         685,8 (27,0)         685,8 (27,0)         685,8 (27,0)
   BLOWER INLET P MM. H2O(IN. H2O)         530,9 (20,9)         530,9 (20,9)         530,9 (20,9)         530,9 (20,9)
   BLOWER INLET TEMP. DEG. C(DEG. F)        48.9 (120,0)         48,9 (120,0)         48,9 (120,0)         48,9 (120,0)
   BLOWER REVOLUTIONS                          6180.                6264.                6371,                6201,
   TIME SECONDS                                296,0                300,0                305,0                297,0
   TOTAL FLOW STD. CU. METRES(SCF)         299.9 (10594,)       304,0 (10738,)       309,2 (10922,)       301,0 (10630,)

   HC  SAMPLE METER/RANGE/PPM              6.3/22/  31.         7,8/22/  39,         13,1/22/  66,        5,7/22/  28,
   HC  BCKGRD METER/RANGE/PPM              10,2/ 1/  10.        8,2/ 1/   8,         11,3/ 1/  11,        8,8/ 1/   9,
   CO  SAMPLE METER/RANGE/PPM              95.8/13/  97.        51,3/12/ 109,        65,4/12/ 146,        82,3/13/  82,
   CO  BCKGRD METER/RANGE/PPM              1.8/13/   2,         ,8/12/   1,           ,7/12/   1.         2,2/13/   2,
   CO2 SAMPLE METER/RANGE/PCT              17,5/ 3/  ,28        26,0/ 3/  ,43         62,6/ 3/ 1,11        17,0/ 3/  ,27
   CO2 BCKGRD METER/RANGE/PCT              3,3/ 3/  ,05         3,4/ 3/  ,05          3,0/ 3/  ,05         3,4/ 3/  ,05
   NOX SAMPLE METER/RANGE/PPM              8,6/13/  26.         10,0/13/  30,         24,9/13/  75,        9,2/13/  27,
   NOX BCKGRD METER/RANGE/PPM               ,8/ 2/   1,          ,8/ 2/   1,           ,8/ 2/   1,          ,8/ 2/   1,

   DILUTION FACTOR                              45.86                30,48                11,80                47,51
   HC  CONCENTRATION PPM                        21,                  31.                  55,                  20,
   CO  CONCENTRATION PPM                        95.                  106,                 141,                 80,
   CO2 CONCENTRATION PCT                        .23                  ,37                  1,07                 ,22
   NOX CONCENTRATION PPM                        25,0                 29,2                 74,1                 26,7

   HC  MASS GRAMS                               3,70                 5,43                 9,86                 3,43
   CO  MASS GRAMS                               33,03                37,57                50,76                27,89
   CO2 MASS GRAMS                               1263.5               2086,0               6075,0               1213,1
   NOX MASS GRAMS                               14,37                16,97                43,80                15,38
   FUEL KG (LB)                            ,558 (    1,23)     ,986 (    2,17)     2,916 (    6,43)      ,551 (    1,21)
   KW HR (HP HR)                           1,12 (    1,51)     2,13 (    2,86)     7,19 (    9,64)      1,15 (    1,54)

   BSHC G/KW HR (G/HP HR)                  3,29 (    2,46)     2,54 (    1,90)     1,37 (    1,02)      2,98 (    2,22)
   BSCO G/KW HR (G/HP HR)                 29,38 (   21,91)    17,61 (   13,13)     7,06 (    5,27)     24,24 (   18,07)
   BSCO2 G/KW HR (G/HP HR)              1123,92 (  838,10)   977,81 (  729,15)   845,16 (  630,24)   1054,19 (  786,11)
   BSNOX G/KW HR (G/HP HR)                12,79 (    9,53)     7,95 (    5,93)     6,09 (    4,54)     13,36 (    9,96)
   BSFC KG/KW HR (LB/HP HR)                .496 (    ,815)     ,462 (    ,760)     ,406 (    ,667)      ,478 (    ,786)

TOTAL TEST RESULTS 4 BAGS                           PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          11,60 ( 15,55)            90MM FILTER
   BSHC   G/KW HR (G/HP HR)     1,93 (  1,44)               SAMPLE FLOW      SCM(SCF)                  1,300 ( 45,92)
   BSCO   G/KW HR (G/HP HR)    12,87 (  9,60)               MULTIPLIER FOR  G/TEST                     ,934
   BSCO2  G/KW HR (G/HP HR)     917. (  684,)               MULTIPLIER FOR  G/KW HR (G/HP HR)          ,0805 ( ,0601)
   BSNOX  G/KW HR (G/HP HR)     7,81 (  5,82)               MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)      ,1864 ( ,0846)
   BSFC  KG/KW HR (LB/HP HR)    .432 (  .710)
                                                         20 X 20 FILTERS
                                                            SAMPLE FLOW     SCM(SCF)                   83,96 (2965,5)
```

PART. G/KW-HR (G/HP-HR) .32 (.24)

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                                        TABLE E-15. ENGINE EMISSION RESULTS                               PROJECT NO. 11-5044-001
                                                        H-TRANS.

ENGINE  NO.D20                                      TEST NO.22-2H  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL                   DATE 10/30/80
ENGINE  9.6 L(586. CID) L-6                         TIME 0                                  DIESEL   EM-465-F
CVS NO.  10                                           DYNO NO.  5                             BAG CART NO.  1

BAROMETER 753.11 MM HG(29.65 IN HG)                 RELATIVE HUMIDITY ,  ENGINE-58. PCT ,  CVS-22. PCT
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)               ABSOLUTE HUMIDITY  9.8 GM/KG( 68.4 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                             1                  2                  3                  4
  DESCRIPTION                                          NYNF               LANF                LAF               NYNF
  BLOWER DIF P MM. H2O(IN. H2O)                    685.8 (27.0)       685.8 (27.0)       685.8 (27.0)       685.8 (27.0)
  BLOWER INLET P MM. H2O(IN. H2O)                  525.8 (20.7)       525.8 (20.7)       525.8 (20.7)       525.8 (20.7)
  BLOWER INLET TEMP. DEG. C(DEG. F)                 48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                                  6181.              6264.              6370.              6202.
  TIME SECONDS                                        296.0              299.9              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)                301.8 (10658.)     305.8 (10801.)     311.0 (10984.)     302.8 (10694.)

  HC  SAMPLE METER/RANGE/PPM                       7.4/22/  37.      9.0/22/  45.     15.7/22/  78.      6.4/22/  32.
  HC  BCKGRD METER/RANGE/PPM                       9.5/ 1/  10.      9.3/ 1/   9.      9.5/ 1/  10.      8.5/ 1/   9.
  CO  SAMPLE METER/RANGE/PPM                      91.4/13/  92.     47.9/12/ 101.     64.6/12/ 144.     79.3/13/  79.
  CO  BCKGRD METER/RANGE/PPM                       1.3/13/   1.       .6/12/   1.       .7/12/   1.       .6/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                      16.6/ 3/  .26     24.9/ 3/  .41     59.7/ 3/ 1.06     17.3/ 3/  .28
  CO2 BCKGRD METER/RANGE/PCT                       3.4/ 3/  .05      3.1/ 3/  .05      2.8/ 3/  .04      2.9/ 3/  .04
  NOX SAMPLE METER/RANGE/PPM                       8.6/13/  26.     10.1/13/  30.     24.4/13/  73.      9.5/13/  29.
  NOX BCKGRD METER/RANGE/PPM                       1.3/ 2/   1.      1.3/ 2/   1.      1.2/ 2/   1.      1.2/ 2/   1.

  DILUTION FACTOR                                    48.33              31.88              12.42              46.67
  HC  CONCENTRATION PPM                              28.                36.                70.                23.
  CO  CONCENTRATION PPM                              90.                98.               139.                78.
  CO2 CONCENTRATION PCT                              .21                .36               1.02                .23
  NOX CONCENTRATION PPM                              24.6               29.0               72.0               27.3

  HC  MASS GRAMS                                     4.82               6.33              12.49               4.09
  CO  MASS GRAMS                                    31.71              34.96              50.29              27.35
  CO2 MASS GRAMS                                  1179.3             2015.6             5795.6             1290.3
  NOX MASS GRAMS                                    14.18              16.96              42.82              15.83
  FUEL KG (LB)                                   .518 (   1.14)    .946 (   2.09)   2.774 (   6.12)    .579 (   1.28)
  KW HR (HP HR)                                  1.11 (   1.48)    2.07 (   2.78)    6.83 (   9.16)    1.19 (   1.59)

  BSHC G/KW HR (G/HP HR)                         4.35 (   3.25)    3.06 (   2.28)    1.83 (   1.36)    3.45 (   2.57)
  BSCO G/KW HR (G/HP HR)                        28.66 (  21.37)   16.88 (  12.59)    7.36 (   5.49)   23.06 (  17.20)
  BSCO2 G/KW HR (G/HP HR)                     1065.80 ( 794.77)  973.05 ( 725.61)  848.08 ( 632.41) 1087.31 ( 811.18)
  BSNOX G/KW HR (G/HP HR)                       12.81 (   9.55)    8.19 (   6.11)    6.27 (   4.67)   13.35 (   9.95)
  BSFC KG/KW HR (LB/HP HR)                       .468 (   .770)    .457 (   .751)    .406 (   .667)    .488 (   .803)

TOTAL TEST RESULTS 4 BAGS                           PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)           11.20 ( 15.02)          90MM FILTER
   BSHC   G/KW HR (G/HP HR)      2.48 (  1.85)             SAMPLE FLOW      SCM(SCF)                 1.375 ( 48.56)
   BSCO   G/KW HR (G/HP HR)     12.89 (  9.61)             MULTIPLIER FOR   G/TEST                    .888
   BSCO2  G/KW HR (G/HP HR)     918.  (  685.)             MULTIPLIER FOR   G/KW HR (G/HP HR)         .0793 ( .0592)
   BSNOX  G/KW HR (G/HP HR)      8.02 (  5.98)             MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)     .1844 ( .0836)
   BSFC  KG/KW HR (LB/HP HR)     .430 (  .707)
                                                        20 X 20 FILTERS
  PART. G/KW-HR (G/HP-HR)  .35 (.26)                       SAMPLE FLOW     SCM(SCF)                 84.62 (2988.7)
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TABLE E-16. ENGINE EMISSION RESULTS

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                                                   H-TRANS.                                        PROJECT NO. 11-5044-001
ENGINE  NO.D20
ENGINE  MODEL   80 VOLVO DUAL FUEL              TEST NO.22-1H  RUN
ENGINE  9.6 L(586. CID) L-6                     DATE 11/19/80
CVS NO.  10                                     TIME 11:43                          DIESEL   EM-465-F
                                                 DYNO NO.  5                         BAG CART NO.  1
BAROMETER 751.08 MM HG(29.57 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)          RELATIVE HUMIDITY ,  ENGINE-45. PCT ,  CVS-22. PCT
                                                ABSOLUTE HUMIDITY  9.3 GM/KG( 65.0 GRAINS/LB)       NOX HUMIDITY C.F. 1.0000
BAG RESULTS
  BAG NUMBER                                          1                2                  3                  4
  DESCRIPTION                                       NYNF             LANF               LAF                NYNF
  BLOWER DIF P MM. H2O(IN. H2O)               688.3 (27.1)     688.3 (27.1)      688.3 (27.1)       688.3 (27.1)
  BLOWER INLET P MM. H2O(IN. H2O)             533.4 (21.0)     533.4 (21.0)      533.4 (21.0)       533.4 (21.0)
  BLOWER INLET TEMP. DEG. C(DEG. F)            48.9 (120.0)     48.9 (120.0)      48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                             6182.            6265.             6371.              6202.
  TIME SECONDS                                   296.0            300.0             305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)            300.6 (10618.)   304.7 (10761.)    309.8 (10943.)     301.6 (10652.)

  HC  SAMPLE METER/RANGE/PPM                  7.4/22/  37.     8.6/22/  43.     14.9/22/  75.       6.4/22/  32.
  HC  BCKGRD METER/RANGE/PPM                  7.7/ 1/   8.     7.5/ 1/   8.      8.5/ 1/   9.       7.2/ 1/   7.
  CO  SAMPLE METER/RANGE/PPM                 51.0/12/ 108.    47.2/12/  99.     52.1/12/ 111.      89.8/13/  90.
  CO  BCKGRD METER/RANGE/PPM                   .6/12/   1.      .7/12/   1.       .8/12/   1.       1.5/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                 17.1/ 3/  .27    26.1/ 3/  .43     61.1/ 3/ 1.08      16.7/ 3/  .27
  CO2 BCKGRD METER/RANGE/PCT                  2.8/ 3/  .04     2.8/ 3/  .04      2.5/ 3/  .04       2.4/ 3/  .04
  NOX SAMPLE METER/RANGE/PPM                  7.2/13/  22.     8.7/13/  26.     24.3/13/  73.       8.3/13/  25.
  NOX BCKGRD METER/RANGE/PPM                   .5/ 2/   1.      .5/ 2/   1.       .5/ 2/   1.        .5/ 2/   1.

  DILUTION FACTOR                               46.66            30.39             12.15              48.16
  HC  CONCENTRATION PPM                          29.              36.               67.                25.
  CO  CONCENTRATION PPM                         106.              96.              107.                88.
  CO2 CONCENTRATION PCT                          .23              .39              1.05                .23
  NOX CONCENTRATION PPM                         21.3             25.6              72.5               24.5

  HC  MASS GRAMS                                5.10             6.32             11.94               4.38
  CO  MASS GRAMS                               37.10            34.17             38.49              30.87
  CO2 MASS GRAMS                              1271.0           2150.2            5956.3             1271.4
  NOX MASS GRAMS                               12.22            14.91             42.96              14.15
  FUEL KG (LB)                                  .564 (   1.24)  1.011 (   2.23)   2.841 (   6.26)     .581 (   1.28)
  KW HR (HP HR)                                 1.11 (   1.49)   2.11 (   2.83)    7.12 (   9.55)     1.11 (   1.49)

  BSHC G/KW HR (G/HP HR)                        4.60 (   3.43)   2.99 (   2.23)    1.68 (   1.25)     3.95 (   2.95)
  BSCO G/KW HR (G/HP HR)                       33.45 (  24.95)  16.19 (  12.07)    5.40 (   4.03)    27.83 (  20.75)
  BSCO2 G/KW HR (G/HP HR)                    1146.00 ( 854.57) 1019.06 ( 759.92) 836.16 ( 623.52)  1146.33 ( 854.82)
  BSNOX G/KW HR (G/HP HR)                      11.02 (   8.22)   7.07 (   5.27)    6.03 (   4.50)    12.76 (   9.51)
  BSFC KG/KW HR (LB/HP HR)                      .509 (   .836)   .479 (   .788)    .399 (   .656)     .524 (   .861)
TOTAL TEST RESULTS 4 BAGS
                                                 PARTICULATE DATA, TOTAL FOR 4 BAGS
 TOTAL KW HR (HP HR)          11.45 ( 15.36)
  BSHC   G/KW HR (G/HP HR)     2.42 (  1.81)          90MM FILTER
  BSCO   G/KW HR (G/HP HR)    12.28 (  9.16)              SAMPLE FLOW     SCM(SCF)                  1.375 ( 48.56)
  BSCO2  G/KW HR (G/HP HR)    930.  ( 693.)               MULTIPLIER FOR  G/TEST                     .885
  BSNOX  G/KW HR (G/HP HR)     7.36 (  5.49)              MULTIPLIER FOR  G/KW HR (G/HP HR)          .0773 ( .0576)
  BSFC  KG/KW HR (LB/HP HR)    .436 (  .717)              MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)      .1771 ( .0803)
```

PART. G/KW-HR (G/HP-HR) .31 (.23)

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                                                      20 X 20 FILTERS
                                                          SAMPLE FLOW     SCM(SCF)                  84.17 (2972.0)
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                                   TABLE E-17. ENGINE EMISSION RESULTS                          PROJECT NO, 11-5044-001
                                                     HOT TRANSIENT

                                         TEST NO,22-18  RUN
ENGINE  NO.D20                           DATE 10/17/80
ENGINE  MODEL  80 VOLVO DUAL FUEL        TIME 10135                          DIESEL   EM-465-F
ENGINE  9.6 L(586. CID) L-6                DYNO NO. 5                          BAG CART NO.  1
CVS NO.  10
                                         RELATIVE HUMIDITY ,  ENGINE-57. PCT ,  CVS-62. PCT
BAROMETER 736,60 MM HG(29.00 IN HG)      ABSOLUTE HUMIDITY 11,6 GM/KG( 81.1 GRAINS/LB)     NOX HUMIDITY C.F. 1,0000
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)

BAG RESULTS
  BAG NUMBER                                  1                    2                    3
  BLOWER DIF P MM. H2O(IN. H2O)          647,7 (25.5)         647.7 (25,5)         647.7 (25,5)
  BLOWER INLET P MM, H2O(IN. H2O)        518,2 (20.4)         518,2 (20.4)         518.2 (20.4)
  BLOWER INLET TEMP. DEG. C(DEG. F)       48.9 (120,0)         48.9 (120,0)         48,9 (120,0)
  BLOWER REVOLUTIONS                        5693.                6009.                5695.
  TIME SECONDS                             272,6                287,8                272,7
  TOTAL FLOW STD. CU. METRES(SCF)        271.2 ( 9579.)       286.3 (10110.)       271.3 ( 9582.)

  HC  SAMPLE MFTER/RANGE/PPM              7,9/22/  40.         8,2/22/  41.         8,0/22/  40.
  HC  BCKGRD MFTER/RANGE/PPM             11.7/ 1/  12.         9,4/ 1/   9.         9,5/ 1/  10.
  CO  SAMPLE MFTER/RANGE/PPM             57.2/12/ 124.        68,9/12/ 156.        51,7/12/ 110.
  CO  BCKGRD MFTER/RANGE/PPM               .6/12/   1.          ,5/12/   1.          .5/12/   1.
  CO2 SAMPLE MFTER/RANGE/PCT             21.3/ 3/  .34        25,0/ 3/  .41        20,9/ 3/  .34
  CO2 BCKGRD MFTER/RANGE/PCT              3.2/ 3/  .05         3,6/ 3/  ,06         3.3/ 3/  ,05
  NOX SAMPLE MFTER/RANGE/PPM              7.7/13/  23.         9,5/13/  28.         9,1/13/  27.
  NOX BCKGRD MFTER/RANGE/PPM               .7/ 2/   1.          .7/ 2/   1.          ,8/ 2/   1.

  DILUTION FACTOR                          37.24                31,39                38,10
  HC  CONCENTRATION PPM                    28,                  32.                  31.
  CO  CONCENTRATION PPM                   120.                 151.                 106.
  CO2 CONCENTRATION PCT                     .30                  ,35                  ,29
  NOX CONCENTRATION PPM                    22.3                 27.7                 26,6

  HC  MASS GRAMS                            4.42                 5,27                 4,83
  CO  MASS GRAMS                           37.84                50,28                33,59
  CO2 MASS GRAMS                         1470.6               1856,6               1429,6
  NOX MASS GRAMS                           11.57                15,16                13,82
  FUEL KG (LB)                              .668 (   1,47)       ,899 (   1,98)       ,657 (   1,45)
  KW HR (HP HR)                            1.39 (   1,86)       2,13 (   2,86)       1,37 (   1,84)

  BSHC G/KW HR (G/HP HR)                   3,18 (   2,37)       2,47 (   1.84)       3,52 (   2,63)
  BSCO G/KW HR (G/HP HR)                  27,23 (  20,30)      23,57 (  17,58)      24,48 (  18,26)
  BSCO2 G/KW HR (G/HP HR)               1058,15 ( 789,06)     870,29 ( 648,97)    1041,89 ( 776,94)
  BSNOX G/KW HR (G/HP HR)                  8,32 (   6,21)       7,11 (   5,30)      10,07 (   7,51)
  BSFC KG/KW HR (LB/HP HR)                 .481 (   ,791)       ,421 (   ,692)       ,479 (   ,787)

                                              PARTICULATE DATA, TOTAL FOR 3 BAGS
TOTAL TEST RESULTS 3 BAGS
                                                 90MM FILTER
  TOTAL KW HR (HP HR)         4,90 (  6,56)            SAMPLE FLOW      SCM(SCF)                 ,859 ( 30,34)
   BSHC   G/KW HR (G/HP HR)   2,97 (  2,21)            MULTIPLIER FOR  G/TEST                    ,965
   BSCO   G/KW HR (G/HP HR)  24,86 ( 18,54)            MULTIPLIER FOR  G/KW HR (G/HP HR)         ,1971 ( ,1470)
   BSCO2  G/KW HR (G/HP HR)   972. (  725.)            MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)     ,4338 ( ,1967)
   BSNOX  G/KW HR (G/HP HR)   8,28 (  6,18)
   BSFC   KG/KW HR (LB/HP HR) .454 (  .747)        20 X 20 FILTERS
                                                       SAMPLE FLOW     SCM(SCF)                  55,25 (1951,3)
 PART. G/KW-HR (G/HP-HR) .59 (.44)
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TABLE E-18. ENGINE EMISSION RESULTS
HOT TRANSIENT

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                                                                                                      PROJECT NO, 11-5044-001

ENGINE  NO.D20                                         TEST NO.22-2B  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL                     DATE 10/17/80
ENGINE  9.6 L(586. CID) L-6                            TIME 11110                            DIESEL   EM-465-F
CVS NO.  10                                              DYNO NO.  5                          BAG CART NO.  1

BAROMETER 736.60 MM HG(29.00 IN HG)                    RELATIVE HUMIDITY ,  ENGINE=53. PCT ,  CVS=60. PCT
DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)                  ABSOLUTE HUMIDITY 11.6 GM/KG( 81.3 GRAINS/LB)       NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                                1                  2                   3
   BLOWER DIF P MM. H2O(IN. H2O)                     650,2 (25,6)       650,2 (25,6)        650,2 (25,6)
   BLOWER INLET P MM. H2O(IN. H2O)                   518,2 (20,4)       518,2 (20,4)        518,2 (20,4)
   BLOWER INLET TEMP. DEG. C(DEG. F)                  48,9 (120,0)       48,9 (120,0)        48,9 (120,0)
   BLOWER REVOLUTIONS                                   5695.              6010.               5695.
   TIME SECONDS                                         272,7              287,8               272,7
   TOTAL FLOW STD. CU. METRES(SCF)                   271,3 ( 9581,)     286,3 (10111,)      271,3 ( 9581,)

   HC  SAMPLE METER/RANGE/PPM                        7,7/22/  38,       7,6/22/  38,        7,3/22/  37,
   HC  BCKGRD METER/RANGE/PPM                        8,7/ 1/   9,       8,6/ 1/   9,        8,1/ 1/   8,
   CO  SAMPLE METER/RANGE/PPM                       55,4/12/ 120,      65,1/12/ 145,       51,4/12/ 109,
   CO  BCKGRD METER/RANGE/PPM                         ,5/12/   1,        ,5/12/   1,         ,5/12/   1,
   CO2 SAMPLE METER/RANGE/PCT                       20,7/ 3/  ,33      23,7/ 3/  ,39       21,0/ 3/  ,34
   CO2 BCKGRD METER/RANGE/PCT                        3,4/ 3/  ,05       3,5/ 3/  ,05        3,4/ 3/  ,05
   NOX SAMPLE METER/RANGE/PPM                        7,4/13/  22,       8,4/13/  25,        8,0/13/  24,
   NOX BCKGRD METER/RANGE/PPM                         ,9/ 2/   1,        ,8/ 2/   1,         ,8/ 2/   1,

   DILUTION FACTOR                                      38,39              33,25               37,96
   HC  CONCENTRATION PPM                                30,                29,                 29,
   CO  CONCENTRATION PPM                               116,               141,                106,
   CO2 CONCENTRATION PCT                                ,28                ,33                 ,29
   NOX CONCENTRATION PPM                                21,3               24,3                23,1

   HC  MASS GRAMS                                       4,66               4,86                4,51
   CO  MASS GRAMS                                      36,50              46,88               33,38
   CO2 MASS GRAMS                                    1404,9             1745,9              1430,4
   NOX MASS GRAMS                                      11,05              13,30               12,01
   FUEL KG (LB)                                       ,643 (   1,42)     ,843 (   1,86)      ,657 (   1,45)
   KW HR (HP HR)                                      1,42 (   1,90)     2,11 (   2,83)      1,40 (   1,88)

   BSHC G/KW HR (G/HP HR)                             3,29 (   2,46)     2,31 (   1,72)      3,22 (   2,40)
   BSCO G/KW HR (G/HP HR)                            25,77 (  19,22)    22,25 (  16,59)     23,86 (  17,80)
   BSCO2 G/KW HR (G/HP HR)                          991,94 ( 739,64)   828,68 ( 617,95)   1022,72 ( 762,65)
   BSNOX G/KW HR (G/HP HR)                            7,80 (   5,82)     6,31 (   4,71)      8,59 (   6,40)
   BSFC KG/KW HR (LB/HP HR)                           ,454 (   ,747)     ,400 (   ,657)      ,470 (   ,773)

TOTAL TEST RESULTS 3 BAGS                                   PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)            4,92 (  6,60)                  90MM FILTER
   BSHC    G/KW HR (G/HP HR)     2,85 (  2,13)                       SAMPLE FLOW      SCM(SCF)                    ,862 ( 30,43)
   BSCO    G/KW HR (G/HP HR)    23,72 ( 17,69)                       MULTIPLIER FOR   G/TEST                      ,962
   BSCO2   G/KW HR (G/HP HR)    931, (  694,)                        MULTIPLIER FOR   G/KW HR (G/HP HR)           ,1954 ( ,1457)
   BSNOX   G/KW HR (G/HP HR)     7,39 (  5,51)                       MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)       ,4488 ( ,2036)
   BSFC    KG/KW HR (LB/HP HR)   ,436 (  ,716)
Part. G/KW-HR (G/HP-Hr) .63 (.47)                               20 X 20 FILTERS
                                                                    SAMPLE FLOW     SCM(SCF)                      55,24 (1951,2)
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TABLE E-19. ENGINE EMISSION RESULTS HOT TRANSIENT

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                                                              ENGINE EMISSION RESULTS
                                                                  HOT TRANSIENT                                  PROJECT NO. 11-5044-001

ENGINE  NO.020                                    TEST NO.22-28  RUN
ENGINE  MODEL   80 VOLVO DUAL FUEL                DATE 10/30/80                              DIESEL   EM-465-F
ENGINE  9.6 L(586. CID) L-6                       TIME                                         BAG CART NO.  1
CVS NO.  10                                         DYNO NO.  5

BAROMETER 753.11 MM HG(29.65 IN HG)               RELATIVE HUMIDITY , ENGINE-54. PCT , CVS-20. PCT
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)             ABSOLUTE HUMIDITY 10.4 GM/KG( 72.9 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                          1                   2                   3
   BLOWER DIF P MM. H2O(IN. H2O)                  685.8 (27.0)        685.8 (27.0)        685.8 (27.0)
   BLOWER INLET P MM. H2O(IN. H2O)                525.8 (20.7)        525.8 (20.7)        525.8 (20.7)
   BLOWER INLET TEMP. DEG. C(DEG. F)               48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
   BLOWER REVOLUTIONS                               5694.               6011.               5693.
   TIME SECONDS                                     272.7               287.8               272.7
   TOTAL FLOW STD. CU. METRES(SCF)                277.6 ( 9803.)      293.0 (10349.)      277.5 ( 9802.)

   HC  SAMPLE METER/RANGE/PPM                       7.2/22/  36.        7.4/22/  37.        7.3/22/  36.
   HC  BCKGRD METER/RANGE/PPM                       8.3/ 1/   8.        7.7/ 1/   8.        8.0/ 1/   8.
   CO  SAMPLE METER/RANGE/PPM                      53.3/12/ 114.       62.6/12/ 139.       47.9/12/ 101.
   CO  BCKGRD METER/RANGE/PPM                        .5/12/   1.         .5/12/   1.         .6/12/   1.
   CO2 SAMPLE METER/RANGE/PCT                      20.2/ 3/  .33       23.1/ 3/  .37       20.1/ 3/  .32
   CO2 BCKGRD METER/RANGE/PCT                       2.7/ 3/  .04        2.3/ 3/  .04        2.5/ 3/  .04
   NOX SAMPLE METER/RANGE/PPM                       7.7/13/  23.        9.5/13/  28.        9.1/13/  27.
   NOX BCKGRD METER/RANGE/PPM                        .9/ 2/   1.         .1/ 2/   0.         .2/ 2/   0.

   DILUTION FACTOR                                  39.42               34.18               39.77
   HC  CONCENTRATION PPM                            28.                 30.                 29.
   CO  CONCENTRATION PPM                            112.                136.                98.
   CO2 CONCENTRATION PCT                            .28                 .34                 .29
   NOX CONCENTRATION PPM                            22.1                28.3                27.2

   HC  MASS GRAMS                                   4.45                4.99                4.58
   CO  MASS GRAMS                                   36.14               46.32               31.80
   CO2 MASS GRAMS                                   1447.7              1827.6              1454.0
   NOX MASS GRAMS                                   11.73               15.85               14.45
   FUEL KG (LB)                                     .674 (   1.49)      .879 (   1.94)      .661 (   1.46)
   KW HR (HP HR)                                    1.41 (   1.89)      2.05 (   2.75)      1.35 (   1.80)

   BSHC G/KW HR (G/HP HR)                           3.16 (   2.36)      2.43 (   1.81)      3.41 (   2.54)
   BSCO G/KW HR (G/HP HR)                          25.68 (  19.15)     22.56 (  16.82)     23.63 (  17.62)
   BSCO2 G/KW HR (G/HP HR)                       1028.55 ( 766.99)    889.92 ( 663.61)   1080.62 ( 805.82)
   BSNOX G/KW HR (G/HP HR)                          8.33 (   6.21)      7.72 (   5.75)     10.74 (   8.01)
   BSFC KG/KW HR (LB/HP HR)                         .479 (   .788)      .428 (   .703)      .491 (   .807)

TOTAL TEST RESULTS 3 BAGS                                   PARTICULATE DATA, TOTAL FOR 3 BAGS

   TOTAL KW HR (HP HR)              4.81 (   6.45)          90MM FILTER
    BSHC    G/KW HR (G/HP HR)       2.92 (   2.18)             SAMPLE FLOW      SCM(SCF)                    .917 ( 32.37)
    BSCO    G/KW HR (G/HP HR)      23.77 (  17.73)             MULTIPLIER FOR   G/TEST                      .925
    BSCO2   G/KW HR (G/HP HR)      984.  (   734.)             MULTIPLIER FOR   G/KW HR (G/HP HR)           .1925 ( .1436)
    BSNOX   G/KW HR (G/HP HR)       8.74 (   6.52)             MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)       .4180 ( .1896)
    BSFC   KG/KW HR (LB/HP HR)      .461 (   .757)
                                                            20 X 20 FILTERS
                                                               SAMPLE FLOW     SCM(SCF)                    57.59 (2033.9)
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PART. G/KW-HR (G/HP-HR) .60 (.45)

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                                         TABLE E-20. ENGINE EMISSION RESULTS
                                                          H-TRANS.                                      PROJECT NO. 11-5044-001
ENGINE  NO.D20                                     TEST NO.22-1B  RUN
ENGINE  MODEL   80 VOLVO DUALFUEL                  DATE 11/19/80
ENGINE  9.6 L(586. CID) L-6                        TIME 01:20                                   DIESEL   EM-465-F
CVS NO.  10                                          DYNO NO.  5                                  BAG CART NO.  1

BAROMETER 740.54 mm HG(29.47 IN HG)                RELATIVE HUMIDITY , ENGINE-57. PCT , CVS-19. PCT
DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)              ABSOLUTE HUMIDITY  9.9 GM/KG( 69.4 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                             1                   2                   3
  BLOWER DIF P MM. H2O(IN. H2O)                   683.3 (26.9)        683.3 (26.9)        683.3 (26.9)
  BLOWER INLET P MM. H2O(IN. H2O)                 528.3 (20.8)        528.3 (20.8)        528.3 (20.8)
  BLOWER INLET TEMP. DEG. C(DEG. F)                48.9 (120.0)        48.9 (120.0)        48.9 (120.0)
  BLOWER REVOLUTIONS                                 5694.               6009.               5694.
  TIME SECONDS                                       272.6               287.8               272.7
  TOTAL FLOW STD. CU. METRES(SCF)                 276.1 ( 9752.)      291.4 (10292.)      276.1 ( 9752.)

  HC  SAMPLE METER/RANGE/PPM                       8.1/22/  41.        7.9/22/  40.        7.5/22/  37.
  HC  BCKGRD METER/RANGE/PPM                       8.6/ 1/   9.        8.9/ 1/   9.       10.3/ 1/  10.
  CO  SAMPLE METER/RANGE/PPM                      57.3/12/ 124.       64.5/12/ 144.       50.3/12/ 107.
  CO  BCKGRD METER/RANGE/PPM                        .9/12/   2.        1.0/12/   2.         .9/12/   2.
  CO2 SAMPLE METER/RANGE/PCT                      20.2/ 3/  .33       24.6/ 3/  .40       21.1/ 3/  .34
  CO2 BCKGRD METER/RANGE/PCT                       3.2/ 3/  .05        3.2/ 3/  .05        3.6/ 3/  .06
  NOX SAMPLE METER/RANGE/PPM                       7.4/13/  22.        9.3/13/  28.        8.0/13/  24.
  NOX BCKGRD METER/RANGE/PPM                        .5/ 2/   1.         .5/ 2/   1.         .5/ 2/   1.

  DILUTION FACTOR                                    39.25               32.00               37.78
  HC  CONCENTRATION PPM                              32.                 31.                 27.
  CO  CONCENTRATION PPM                             121.                140.                104.
  CO2 CONCENTRATION PCT                               .28                 .35                 .29
  NOX CONCENTRATION PPM                              21.7                27.4                23.6

  HC  MASS GRAMS                                      5.14                5.19                4.37
  CO  MASS GRAMS                                     39.00               47.50               33.34
  CO2 MASS GRAMS                                   1402.1              1884.6              1449.4
  NOX MASS GRAMS                                     11.46               15.29               12.46
  FUEL KG (LB)                                        .671 (   1.48)      .905 (   1.99)      .680 (   1.50)
  KW HR (HP HR)                                      1.36 (   1.83)      2.16 (   2.89)      1.36 (   1.83)

  BSHC G/KW HR (G/HP HR)                             3.78 (   2.82)      2.41 (   1.80)      3.21 (   2.40)
  BSCO G/KW HR (G/HP HR)                            28.64 (  21.36)     22.04 (  16.44)     24.49 (  18.26)
  BSCO2 G/KW HR (G/HP HR)                         1029.76 ( 767.89)    874.52 ( 652.13)   1064.49 ( 793.79)
  BSNOX G/KW HR (G/HP HR)                            8.42 (   6.28)      7.10 (   5.29)      9.15 (   6.82)
  BSFC KG/KW HR (LB/HP HR)                           .493 (   .810)      .420 (   .690)      .499 (   .821)

TOTAL TEST RESULTS 3 BAGS                             PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)          4.88 (  6.54)             90MM FILTER
   BSHC   G/KW HR (G/HP HR)    3.02 (  2.25)                SAMPLE FLOW      SCM(SCF)                   .879 ( 31.03)
   BSCO   G/KW HR (G/HP HR)   24.57 ( 18.32)                MULTIPLIER FOR  G/TEST                      .960
   BSCO2  G/KW HR (G/HP HR)   971.  (  724.)                MULTIPLIER FOR  G/KW HR (G/HP HR)           .1968 ( .1468)
   BSNOX  G/KW HR (G/HP HR)    8.04 (  5.99)                MULTIPLIER FOR  G/KG FUEL (G/LB FUEL)       .4257 ( .1931)
   BSFC  KG/KW HR (LB/HP HR)   .462 (  .760)
                                                         20 X 20 FILTERS
   PART. G/KW-HR (G/HP-HR)  .59 (.44)                       SAMPLE FLOW     SCM(SCF)                    58.50 (2066.3)
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APPENDIX F

TRANSIENT TEST RESULTS FROM THE ETHANOL-CATALYST CONFIGURATION

TABLE F-1. NOTES CONCERNING TEST RESULTS GIVEN IN APPENDIX F

Table No.	Notes
Ethanol & Catalyst & B.P.	Preparations for runs with ethanol with catalyst and back-pressure device, included, resetting of diesel fuel flow at idle and efforts to reduce the driveline vibration which had increased significantly from the start of test work on this engine. As a result of severe driveline vibration a larger torque meter (100K) was installed.
Cold Start	
F-2	Failed statistical requirements, torque intercept -23.6 and power slope was 9 percent high. Results used for regulated emission. NO_x by bag measurement was 7.51 g/kW-hr.
F-3	Failed statistical requirements, torque intercept -25.5. Cycle power was 15 percent below command cycle power. Results used for regulated emissions, NO_x by bag measurement was 7.98 g/kW-hr.
F-4	Failed statistical requirements, torque intercept -24.1. Results used for regulated emissions. NO_x by bag measurement was 8.04 g/kW-hr.
Hot Start	
F-5	Failed statistical requirements, torque slope 1.086 and power slope 1.117. Results used for regulated emissions. NO_x by bag measurement was 7.24 g/kW-hr.
F-6	Failed statistical requirements, torque intercept -15.7. Results used for regulated emissions. NO_x by bag measurement was 7.59 g/kW-hr.
F-7	Failed statistical requirements, torque intercept -18.0. torque and power R^2 were .86 and .89 respectively. Results used for regulated emissions.
Bus Cycle	
F-8	Failed statistical requirements, torque R^2 0.872. Results used for regulated emissions.
F-9	Failed statistical requirements, torque R^2 0.0866. Results used for regulated emissions.

TABLE F-2. ENGINE EMISSION RESULTS
C-TRANS.

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                                                                                  PROJECT NO. 11-5044-001

ENGINE  NO.D23                              TEST NO.23-3C  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL           DATE 11/ 6/80
ENGINE  9.6 L(586. CID) L-6                 TIME :::::                   DIESEL   EM-465-F
CVS NO.  10                                   DYNO NO.  5                  BAG CART NO.  1

BAROMETER 744.98 MM HG(29.33 IN HG)         RELATIVE HUMIDITY , ENGINE-60. PCT ,  CVS-32. PCT
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)       ABSOLUTE HUMIDITY 10.2 GM/KG( 71.6 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                      1                  2                  3                  4
  DESCRIPTION                                   NYNF               LANF                LAF               NYNF
  BLOWER DIF P MM. H20(IN. H20)            680.7 (26.8)       680.7 (26.8)       680.7 (26.8)       680.7 (26.8)
  BLOWER INLET P MM. H20(IN. H20)          528.3 (20.8)       528.3 (20.8)       528.3 (20.8)       528.3 (20.8)
  BLOWER INLET TEMP. DEG. C(DEG. F)         48.9 (120.0)       48.9 (120.0)       48.9 (120.0)       48.9 (120.0)
  BLOWER REVOLUTIONS                          6182.              6265.              6371.              6202.
  TIME SECONDS                                296.0              300.0              305.0              297.0
  TOTAL FLOW STD. CU. METRES(SCF)          298.2 (10532.)     302.2 (10673.)     307.3 (10854.)     299.1 (10566.)

  HC   SAMPLE METER/RANGE/PPM               5.3/22/  27.       4.3/22/  22.       4.2/22/  21.       2.7/22/  13.
  HC   BCKGRD METER/RANGE/PPM               9.8/ 1/  10.       9.4/ 1/   9.      10.0/ 1/  10.       9.8/ 1/  10.
  CO   SAMPLE METER/RANGE/PPM              49.2/12/ 104.      49.9/13/  47.      29.2/13/  26.      28.1/13/  25.
  CO   BCKGRD METER/RANGE/PPM                .5/12/   1.       1.1/13/   1.       1.1/13/   1.       1.4/13/   1.
  CO2  SAMPLE METER/RANGE/PCT              20.6/ 3/  .33      29.0/ 3/  .48      66.1/ 3/ 1.19      19.0/ 3/  .30
  CO2  BCKGRD METER/RANGE/PCT               3.2/ 3/  .05       3.0/ 3/  .05       2.9/ 3/  .04       3.0/ 3/  .05
  NOX  SAMPLE METER/RANGE/PPM               8.3/13/  25.       9.9/13/  30.      25.0/13/  75.       9.5/13/  28.
  NOX  BCKGRD METER/RANGE/PPM                .9/ 2/   1.       1.0/ 2/   1.       1.0/ 2/   1.       1.1/ 2/   1.

  DILUTION FACTOR                           38.87              27.65              11.26              43.43
  HC   CONCENTRATION PPM                    17.                13.                12.                 4.
  CO   CONCENTRATION PPM                   101.                45.                25.                24.
  CO2  CONCENTRATION PCT                     .28                .43               1.14                .26
  NOX  CONCENTRATION PPM                    23.9               28.7               74.2               27.3

  HC   MASS GRAMS                            2.92               2.19               2.07                .65
  CO   MASS GRAMS                           35.17              15.90               8.82               8.27
  CO2  MASS GRAMS                         1551.4             2399.7             6442.0             1423.6
  NOX  MASS GRAMS                           13.65              16.59              43.59              15.62
  FUEL KG (LB)                               .653 (   1.44)    1.097 (   2.42)    3.051 (   6.73)     .615 (   1.36)
  KW HR (HP HR)                             1.02 (   1.37)     2.06 (   2.77)     7.39 (   9.91)     1.15 (   1.54)

  BSHC G/KW HR (G/HP HR)                    2.87 (   2.14)     1.06 (    .79)      .28 (    .21)      .56 (    .42)
  BSCO G/KW HR (G/HP HR)                   34.55 (  25.77)     7.71 (   5.75)     1.19 (    .89)     7.19 (   5.36)
  BSCO2 G/KW HR (G/HP HR)                1523.96 (1136.42)  1163.48 ( 867.61)   871.54 ( 649.91)  1237.04 ( 922.46)
  BSNOX G/KW HR (G/HP HR)                  13.41 (  10.00)     8.04 (   6.00)     5.90 (   4.40)    13.57 (  10.12)
  BSFC KG/KW HR (LB/HP HR)                  .642 (  1.055)     .532 (   .875)     .413 (   .678)     .535 (   .879)

TOTAL TEST RESULTS 4 BAGS                           PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          11.62 ( 15.59)         90MM FILTER
   BSHC   G/KW HR (G/HP HR)      .67 (   .50)            SAMPLE FLOW      SCM(SCF)                 1.237 ( 43.71)
   BSCO   G/KW HR (G/HP HR)     5.87 (  4.37)            MULTIPLIER FOR   G/TEST                    .975
   BSCO2  G/KW HR (G/HP HR)    1017. (  758.)            MULTIPLIER FOR   G/KW HR (G/HP HR)         .0839 ( .0626)
   BSNOX  G/KW HR (G/HP HR)     7.70 (  5.74)            MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)     .1800 ( .0817)
   BSFC  KG/KW HR (LB/HP HR)    .466 (  .766)
                                                      20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .34 (.25)                       SAMPLE FLOW      SCM(SCF)                 83.40 (2945.6)
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                                      TABLE F-3. ENGINE EMISSION RESULTS
                                                  C-TRANS.                                           PROJECT NO. 11-5044-001

ENGINE  NO.D20                                  TEST NO.D23-1  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL               DATE 11/10/80
ENGINE  9.6 L(586. CID) L-6                     TIME :::::                          DIESEL   EM-465-F
CVS NO.  10                                       DYNO NO.  5                          BAG CART NO.  1

BAROMETER 742.19 MM HG(29.22 IN HG)             RELATIVE HUMIDITY ,  ENGINE-62. PCT ,  CVS-46. PCT
DRY BULB TEMP. 20.0 DEG C(68.0 DEG F)           ABSOLUTE HUMIDITY  9.2 GM/KG( 64.7 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                          1                  2                  3                  4
  DESCRIPTION                                       NYNF               LANF                LAF               NYNF
  BLOWER DIF P MM. H2O(IN. H2O)               713.7 (28.1)       713.7 (28.1)       713.7 (28.1)       713.7 (28.1)
  BLOWER INLET P MM. H2O(IN. H2O)             546.1 (21.5)       546.1 (21.5)       546.1 (21.5)       546.1 (21.5)
  BLOWER INLET TEMP. DEG. C(DEG. F)            37.8 (100.0)       37.8 (100.0)       37.8 (100.0)       37.8 (100.0)
  BLOWER REVOLUTIONS                              6180.              6264.              6370.              6201.
  TIME SECONDS                                   296.0              300.0              305.0              296.9
  TOTAL FLOW STD. CU. METRES(SCF)             304.0 (10736.)     308.1 (10882.)     313.3 (11066.)     305.0 (10772.)

  HC   SAMPLE METER/RANGE/PPM                 24.2/11/  24.      22.8/11/  23.      24.1/11/  24.      12.3/11/  12.
  HC   BCKGRD METER/RANGE/PPM                  9.8/ 1/  10.       9.2/ 1/   9.       9.3/ 1/   9.       8.8/ 1/   9.
  CO   SAMPLE METER/RANGE/PPM                 87.9/13/  89.      43.3/13/  40.      26.2/13/  24.      24.0/13/  21.
  CO   BCKGRD METER/RANGE/PPM                  1.3/13/   1.       1.1/13/   1.       1.3/13/   1.       1.4/13/   1.
  CO2  SAMPLE METER/RANGE/PCT                 19.0/ 3/  .30      26.1/ 3/  .43      59.8/ 3/ 1.06      17.7/ 3/  .28
  CO2  BCKGRD METER/RANGE/PCT                  3.1/ 3/  .05       2.8/ 3/  .04       2.8/ 3/  .04       2.9/ 3/  .04
  NOX  SAMPLE METER/RANGE/PPM                  9.6/13/  29.      11.2/13/  34.      27.5/13/  82.       9.7/13/  29.
  NOX  BCKGRD METER/RANGE/PPM                   .8/ 2/   1.        .7/ 2/   1.        .6/ 2/   1.        .6/ 2/   1.

  DILUTION FACTOR                                42.43              30.95              12.60              46.83
  HC   CONCENTRATION PPM                          15.                14.                16.                 4.
  CO   CONCENTRATION PPM                          86.                38.                22.                20.
  CO2  CONCENTRATION PCT                          .26                .39               1.02                .24
  NOX  CONCENTRATION PPM                         28.0               33.0               81.9               28.7

  HC   MASS GRAMS                                 2.56               2.46               2.80                .64
  CO   MASS GRAMS                                30.34              13.78               7.91               7.06
  CO2  MASS GRAMS                               1438.2             2174.2             5849.9             1337.2
  NOX  MASS GRAMS                                16.26              19.46              49.07              16.72
  FUEL KG (LB)                                .581 (    1.28)   .980 (    2.16)  2.735 (    6.03)   .568 (    1.25)
  KW HR (HP HR)                                .96 (    1.29)   1.90 (    2.55)   6.55 (    8.78)   1.01 (    1.35)

  BSHC G/KW HR (G/HP HR)                      2.65 (    1.98)   1.29 (     .96)    .43 (     .32)    .64 (     .48)
  BSCO G/KW HR (G/HP HR)                     31.45 (   23.45)   7.24 (    5.40)   1.21 (     .90)   6.99 (    5.21)
  BSCO2 G/KW HR (G/HP HR)                  1490.67 (1111.59) 1142.79 ( 852.18) 893.62 ( 666.37) 1324.05 ( 987.34)
  BSNOX G/KW HR (G/HP HR)                    16.86 (   12.57)  10.23 (    7.63)   7.50 (    5.59)  16.56 (   12.35)
  BSFC KG/KW HR (LB/HP HR)                    .602 (    .990)   .515 (    .847)   .418 (    .687)   .563 (    .925)

TOTAL TEST RESULTS 4 BAGS                        PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          10.42 ( 13.98)         90MM FILTER
   BSHC    G/KW HR (G/HP HR)     .81 (   .61)            SAMPLE FLOW      SCM(SCF)                     1.234 ( 43.59)
   BSCO    G/KW HR (G/HP HR)    5.67 (  4.23)            MULTIPLIER FOR   G/TEST                        .997
   BSCO2   G/KW HR (G/HP HR)   1036. (  773.)            MULTIPLIER FOR   G/KW HR (G/HP HR)             .0956 ( .0713)
   BSNOX   G/KW HR (G/HP HR)    9.74 (  7.26)            MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)         .2049 ( .0930)
   BSFC  KG/KW HR (LB/HP HR)    .467 (  .767)
                                                      20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .31 (.23)                       SAMPLE FLOW     SCM(SCF)                      82.10 (2899.9)
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TABLE F-4. ENGINE EMISSION RESULTS

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                                        C-TRANS.                                   PROJECT NO. 11-5044-001

ENGINE  NO.D20                              TEST NO.D23-2  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL           DATE 11/11/80
ENGINE  9.6 L(586. CID) L-6                 TIME 9:40                              DIESEL   EM-465-F
CVS NO.  10                                   DYNO NO.  5                           BAG CART NO.  1

BAROMETER 744.73 MM HG(29.32 IN HG)         RELATIVE HUMIDITY ,  ENGINE-64. PCT ,  CVS-51. PCT
DRY BULB TEMP. 21.1 DEG C(70.0 DEG F)       ABSOLUTE HUMIDITY 10.1 GM/KG( 70.3 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                      1                  2                  3                  4
  DESCRIPTION                                    NYNF               LANF               LAF                NYNF
  BLOWER DIF P MM. H2O(IN. H2O)             678.2 (26.7)       678.2 (26.7)       678.2 (26.7)       678.2 (26.7)
  BLOWER INLET P MM. H2O(IN. H2O)           525.8 (20.7)       525.8 (20.7)       525.8 (20.7)       525.8 (20.7)
  BLOWER INLET TEMP. DEG. C(DEG. F)          51.7 (125.0)       51.7 (125.0)       51.7 (125.0)       51.7 (125.0)
  BLOWER REVOLUTIONS                            6182.              6266.              6371.              6204.
  TIME SECONDS                                  295.9              299.9              305.0              296.0
  TOTAL FLOW STD. CU. METRES(SCF)           296.0 (10456.)     300.0 (10598.)     305.1 (10775.)     297.1 (10492.)

  HC  SAMPLE METER/RANGE/PPM                27.8/21/  28.      25.4/21/  25.      25.9/21/  26.      15.1/21/  15.
  HC  BCKGRD METER/RANGE/PPM                10.4/ 1/  10.      10.0/ 1/  10.      10.3/ 1/  10.      10.0/ 1/  10.
  CO  SAMPLE METER/RANGE/PPM                91.3/13/  92.      42.4/13/  39.      24.1/13/  22.      25.0/13/  22.
  CO  BCKGRD METER/RANGE/PPM                 1.0/13/   1.       1.0/13/   1.       1.0/13/   1.        .9/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                19.6/ 3/  .31      26.9/ 3/  .44      61.7/ 3/ 1.10      18.7/ 3/  .30
  CO2 BCKGRD METER/RANGE/PCT                 2.7/ 3/  .04       2.7/ 3/  .04       2.7/ 3/  .04       2.8/ 3/  .04
  NOX SAMPLE METER/RANGE/PPM                 8.6/13/  26.      10.4/13/  31.      27.5/13/  83.       9.7/13/  29.
  NOX BCKGRD METER/RANGE/PPM                  .8/ 2/   1.        .7/ 2/   1.        .6/ 2/   1.        .6/ 2/   1.

  DILUTION FACTOR                               41.02              29.96              12.17              44.18
  HC  CONCENTRATION PPM                          18.                16.                16.                 5.
  CO  CONCENTRATION PPM                          89.                38.                20.                21.
  CO2 CONCENTRATION PCT                          .27                .40               1.06                .26
  NOX CONCENTRATION PPM                         25.1               30.4               82.0               28.5

  HC  MASS GRAMS                                3.01               2.73               2.89                .92
  CO  MASS GRAMS                               30.04              13.11               7.10               7.32
  CO2 MASS GRAMS                              1488.6             2203.0             5916.2             1402.4
  NOX MASS GRAMS                               14.19              17.47              47.87              16.17
  FUEL KG (LB)                                  .613 (    1.35)    .994 (    2.19)  2.771 (    6.11)    .597 (    1.32)
  KW HR (HP HR)                                  .99 (    1.33)    1.97 (    2.65)   6.77 (    9.08)    1.04 (    1.39)

  BSHC G/KW HR (G/HP HR)                        3.04 (    2.26)    1.38 (    1.03)    .43 (     .32)     .89 (     .66)
  BSCO G/KW HR (G/HP HR)                       31.09 (   23.18)    6.64 (    4.95)   1.05 (     .78)    7.06 (    5.26)
  BSCO2 G/KW HR (G/HP HR)                    1500.77 (1119.12) 1115.60 (  831.90) 873.67 (  651.49) 1352.44 (1008.51)
  BSNOX G/KW HR (G/HP HR)                      14.31 (   10.67)    8.85 (    6.60)   7.07 (    5.27)   15.59 (   11.63)
  BSFC KG/KW HR (LB/HP HR)                      .618 (   1.016)    .503 (    .828)   .409 (    .673)    .576 (    .947)

TOTAL TEST RESULTS 4 BAGS                           PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          10.78 ( 14.45)         90MM FILTER
   BSHC   G/KW HR (G/HP HR)      .89 (   .66)           SAMPLE FLOW      SCM(SCF)                  1.250 ( 44.15)
   BSCO   G/KW HR (G/HP HR)     5.42 (  4.04)           MULTIPLIER FOR   G/TEST                     .958
   BSCO2  G/KW HR (G/HP HR)    1022. (  762.)           MULTIPLIER FOR   G/KW HR (G/HP HR)          .0890 ( .0663)
   BSNOX  G/KW HR (G/HP HR)     8.88 (  6.62)           MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)      .1926 ( .0874)
   BSFC   KG/KW HR (LB/HP HR)   .462 (  .759)
                                                      20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR) .38 (.28)                       SAMPLE FLOW      SCM(SCF)                  81.60 (2882.2)
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                                   TABLE F-5. ENGINE EMISSION RESULTS
                                                H-TRANS.                                              PROJECT NO. 11-5044-001

ENGINE  NO.D23                                     TEST NO.23-5H  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL                  DATE 11/ 6/80
ENGINE  9.6 L(586. CID) L-6                        TIME :::::                          DIESEL   EM-465-F
CVS NO.  10                                          DYNO NO.  5                         BAG CART NO.  1

BAROMETER 744.98 MM HG(29.33 IN HG)                RELATIVE HUMIDITY ,  ENGINE-47. PCT ,  CVS-32. PCT
DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)              ABSOLUTE HUMIDITY 10.3 GM/KG( 72.4 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                           1                    2                    3                    4
  DESCRIPTION                                        NYNF                 LANF                 LAF                  NYNF
  BLOWER DIF P MM. H2O(IN. H2O)                 683.3 (26.9)         683.3 (26.9)         683.3 (26.9)         683.3 (26.9)
  BLOWER INLET P MM. H2O(IN. H2O)               528.3 (20.8)         528.3 (20.8)         528.3 (20.8)         528.3 (20.8)
  BLOWER INLET TEMP. DEG. C(DEG. F)              50.0 (122.0)         50.0 (122.0)         50.0 (122.0)         50.0 (122.0)
  BLOWER REVOLUTIONS                               6181.                6264.                6372.                6202.
  TIME SECONDS                                    297.0                300.0                305.0                296.9
  TOTAL FLOW STD. CU. METRES(SCF)             297.4 (10505.)       301.4 (10645.)       306.6 (10829.)       298.4 (10540.)

  HC  SAMPLE METER/RANGE/PPM                  18.5/21/  18.        17.0/21/  17.        18.6/21/  19.        11.4/21/  11.
  HC  BCKGRD METER/RANGE/PPM                  10.0/ 1/  10.         9.0/ 1/   9.         8.2/ 1/   8.         8.1/ 1/   8.
  CO  SAMPLE METER/RANGE/PPM                  59.2/13/  57.        41.3/13/  38.        30.1/13/  27.        26.8/13/  24.
  CO  BCKGRD METER/RANGE/PPM                    .9/13/   1.          .7/13/   1.          .8/13/   1.          .7/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                  18.8/ 3/  .30        28.1/ 3/  .46        65.8/ 3/ 1.18        19.0/ 3/  .30
  CO2 BCKGRD METER/RANGE/PCT                   3.2/ 3/  .05         3.0/ 3/  .05         2.8/ 3/  .04         2.8/ 3/  .04
  NOX SAMPLE METER/RANGE/PPM                   7.6/13/  23.        10.6/13/  32.        30.6/13/  92.         8.7/13/  26.
  NOX BCKGRD METER/RANGE/PPM                   1.0/ 2/   1.         1.0/ 2/   1.         1.0/ 2/   1.         1.0/ 2/   1.

  DILUTION FACTOR                                 43.40                28.67                11.32                43.48
  HC  CONCENTRATION PPM                            9.                   8.                  11.                   3.
  CO  CONCENTRATION PPM                           55.                  37.                  26.                  23.
  CO2 CONCENTRATION PCT                            .25                  .42                 1.14                  .26
  NOX CONCENTRATION PPM                           21.9                 30.9                 90.9                 25.2

  HC  MASS GRAMS                                  1.49                 1.44                 1.78                  .60
  CO  MASS GRAMS                                 19.12                12.95                 9.18                 7.98
  CO2 MASS GRAMS                                1380.5               2305.2               6401.0               1436.5
  NOX MASS GRAMS                                 12.44                17.79                53.29                14.39
  FUEL KG (LB)                                   .585 (    1.29)     1.056 (    2.33)     3.029 (    6.68)      .618 (    1.36)
  KW HR (HP HR)                                  1.15 (    1.54)      2.20 (    2.94)      7.44 (    9.98)      1.16 (    1.56)

  BSHC G/KW HR (G/HP HR)                         1.30 (     .97)       .66 (     .49)       .27 (     .20)       .52 (     .39)
  BSCO G/KW HR (G/HP HR)                        16.62 (   12.39)      5.90 (    4.40)      1.23 (     .92)      6.88 (    5.13)
  BSCO2 G/KW HR (G/HP HR)                     1199.64 ( 894.58)   1050.06 ( 783.03)    859.81 ( 641.16)   1238.79 ( 923.77)
  BSNOX G/KW HR (G/HP HR)                       10.81 (    8.06)      8.10 (    6.04)      7.16 (    5.34)     12.41 (    9.26)
  BSFC KG/KW HR (LB/HP HR)                       .508 (    .835)      .481 (    .791)      .407 (    .669)      .533 (    .877)

TOTAL TEST RESULTS 4 BAGS                                  PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          11.95 ( 16.03)                 90MM FILTER
   BSHC   G/KW HR (G/HP HR)      .46 (   .34)                      SAMPLE FLOW      SCM(SCF)                  1.261 ( 44.52)
   BSCO   G/KW HR (G/HP HR)     4.12 (  3.07)                      MULTIPLIER FOR   G/TEST                     .955
   BSCO2  G/KW HR (G/HP HR)     964. (  719.)                      MULTIPLIER FOR   G/KW HR (G/HP HR)          .0799 ( .0596)
   BSNOX  G/KW HR (G/HP HR)     8.19 (  6.11)                      MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)      .1806 ( .0819)
   BSFC  KG/KW HR (LB/HP HR)    .443 (  .727)
                                                             20 X 20 FILTERS
 PART. G/KW-HR (G/HP-HR)   .38 (.28)                              SAMPLE FLOW     SCM(SCF)                    83.26 (2940.6)
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TABLE F-6. ENGINE EMISSION RESULTS
H-TRANS.

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                                                                                      PROJECT NO. 11-5044-001
ENGINE  NO.D20                                 TEST NO.D23-1  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL              DATE 11/10/80
ENGINE  9.6 L(586. CID) L-6                    TIME :::::
CVS NO.  10                                      DYNO NO.  5                    DIESEL   EM-465-F
                                                                                  BAG CART NO.  1
BAROMETER 742.44 MM HG(29.23 IN HG)            RELATIVE HUMIDITY ,  ENGINE-52. PCT ,  CVS-17. PCT
DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)          ABSOLUTE HUMIDITY 10.5 GM/KG( 73.7 GRAINS/LB)       NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                       1                  2                  3                  4
  DESCRIPTION                                    NYNF               LANF               LAF                NYNF
  BLOWER DIF P MM. H2O(IN. H2O)              706.1 (27.8)       706.1 (27.8)       706.1 (27.8)       706.1 (27.8)
  BLOWER INLET P MM. H2O(IN. H2O)            546.1 (21.5)       546.1 (21.5)       546.1 (21.5)       546.1 (21.5)
  BLOWER INLET TEMP. DEG. C(DEG. F)           51.7 (125.0)       51.7 (125.0)       51.7 (125.0)       51.7 (125.0)
  BLOWER REVOLUTIONS                            6202.              6265.              6371.              6203.
  TIME SECONDS                                  297.0              300.0              305.0              296.9
  TOTAL FLOW STD. CU. METRES(SCF)            295.1 (10424.)     298.1 (10530.)     303.2 (10708.)     295.2 (10426.)

  HC   SAMPLE METER/RANGE/PPM                18.6/11/  19.      20.7/11/  21.      23.7/11/  24.      12.9/11/  13.
  HC   BCKGRD METER/RANGE/PPM                 9.6/ 1/  10.       9.4/ 1/   9.      10.0/ 1/  10.       9.9/ 1/  10.
  CO   SAMPLE METER/RANGE/PPM                47.0/13/  44.      37.6/13/  35.      27.3/13/  25.      24.9/13/  22.
  CO   BCKGRD METER/RANGE/PPM                 1.7/13/   1.       1.6/13/   1.       1.3/13/   1.       1.3/13/   1.
  CO2  SAMPLE METER/RANGE/PCT                17.4/ 3/  .28      25.4/ 3/  .41      60.8/ 3/ 1.00      18.3/ 3/  .29
  CO2  BCKGRD METER/RANGE/PCT                 3.1/ 3/  .05       2.8/ 3/  .04       2.8/ 3/  .04       2.7/ 3/  .04
  NOX  SAMPLE METER/RANGE/PPM                 7.8/13/  23.      10.2/13/  31.      27.1/13/  81.       9.0/13/  27.
  NOX  BCKGRD METER/RANGE/PPM                  .1/ 2/   0.        .1/ 2/   0.        .1/ 2/   0.        .1/ 2/   0.

  DILUTION FACTOR                               47.18              31.90              12.37              45.21
  HC   CONCENTRATION PPM                          9.                12.                15.                 3.
  CO   CONCENTRATION PPM                         42.                33.                23.                21.
  CO2  CONCENTRATION PCT                         .23                .37               1.04                .25
  NOX  CONCENTRATION PPM                        23.3               30.6               81.4               27.0

  HC   MASS GRAMS                               1.57               2.00               2.55                .56
  CO   MASS GRAMS                              14.47              11.36               8.08               7.21
  CO2  MASS GRAMS                             1250.4             2037.0             5771.6             1365.1
  NOX  MASS GRAMS                              13.17              17.44              47.18              15.23
  FUEL KG (LB)                                  .485 (   1.07)     .915 (   2.02)    2.696 (   5.94)     .579 (   1.28)
  KW HR (HP HR)                                 1.03 (   1.38)     1.91 (   2.56)     6.54 (   8.77)     1.01 (   1.35)

  BSHC G/KW HR (G/HP HR)                        1.53 (   1.14)     1.05 (    .78)      .39 (    .29)      .55 (    .41)
  BSCO G/KW HR (G/HP HR)                       14.08 (  10.50)     5.94 (   4.43)     1.24 (    .92)     7.14 (   5.32)
  BSCO2 G/KW HR (G/HP HR)                    1216.41 ( 907.08)  1065.61 ( 794.62)   882.87 ( 658.36)  1351.76 (1008.01)
  BSNOX G/KW HR (G/HP HR)                      12.81 (   9.55)     9.12 (   6.80)     7.22 (   5.38)    15.08 (  11.24)
  BSFC KG/KW HR (LB/HP HR)                      .472 (   .776)     .479 (   .707)     .412 (   .678)     .573 (   .942)
TOTAL TEST RESULTS 4 BAGS                        PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)             10.49 ( 14.06)        90MM FILTER
   BSHC    G/KW HR (G/HP HR)        .64 (   .47)            SAMPLE FLOW      SCM(SCF)                   1.267 ( 44.73)
   BSCO    G/KW HR (G/HP HR)       3.92 (  2.92)            MULTIPLIER FOR   G/TEST                      .941
   BSCO2   G/KW HR (G/HP HR)       994. (  741.)            MULTIPLIER FOR   G/KW HR (G/HP HR)           .0877 ( .0669)
   BSNOX   G/KW HR (G/HP HR)       8.87 (  6.61)            MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)       .2013 ( .0913)
   BSFC   KG/KW HR (LB/HP HR)      .446 (  .733)
PART. G/KW-HR (G/HP-HR) .39 (.29)                       20 X 20 FILTERS
                                                           SAMPLE FLOW     SCM(SCF)                    81.58 (2801.2)
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TABLE F-7. ENGINE EMISSION RESULTS

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                                              H-TRANS.                                          PROJECT NO. 11-5044-001

ENGINE  NO.D20                                   TEST NO.D23-2  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL                DATE 11/11/80
ENGINE  9.6 L(586. CID) L-6                      TIME 10:25                         DIESEL   EM-465-F
CVS NO.  10                                        DYNO NO.  5                        BAG CART NO.  1

BAROMETER 744.73 MM HG(29.32 IN HG)              RELATIVE HUMIDITY ,  ENGINE-50. PCT ,  CVS-43. PCT
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)            ABSOLUTE HUMIDITY 10.3 GM/KG( 72.2 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                          1                     2                     3                     4
  DESCRIPTION                                       NYNF                  LANF                  LAF                   NYNF
  BLOWER DIF P MM. H2O(IN. H2O)               680.7 (26.8)          680.7 (26.8)          680.7 (26.8)          680.7 (26.8)
  BLOWER INLET P MM. H2O(IN. H2O)             525.8 (20.7)          525.8 (20.7)          525.8 (20.7)          525.8 (20.7)
  BLOWER INLET TEMP. DEG. C(DEG. F)            51.7 (125.0)          51.7 (125.0)          51.7 (125.0)          51.7 (125.0)
  BLOWER REVOLUTIONS                              6182.                 6266.                 6372.                 6203.
  TIME SECONDS                                   296.0                 300.0                 305.0                 297.0
  TOTAL FLOW STD. CU. METRES(SCF)             295.9 (10452.)        299.9 (10594.)        305.0 (10773.)        296.9 (10488.)

  HC  SAMPLE METER/RANGE/PPM                  20.1/21/  20.         21.9/21/  22.         25.0/21/  25.         14.2/21/  14.
  HC  BCKGRD METER/RANGE/PPM                  10.1/ 1/  10.          9.9/ 1/  10.         10.0/ 1/  10.          9.7/ 1/  10.
  CO  SAMPLE METER/RANGE/PPM                  51.0/13/  48.         37.2/13/  34.         26.2/13/  24.         26.0/13/  23.
  CO  BCKGRD METER/RANGE/PPM                   1.0/13/   1.          1.3/13/   1.          1.5/13/   1.          1.7/13/   1.
  CO2 SAMPLE METER/RANGE/PCT                  17.8/ 3/  .28         24.9/ 3/  .41         61.2/ 3/ 1.09         18.0/ 3/  .29
  CO2 BCKGRD METER/RANGE/PCT                   3.1/ 3/  .05          2.7/ 3/  .04          2.7/ 3/  .04          2.6/ 3/  .04
  NOX SAMPLE METER/RANGE/PPM                   7.6/13/  23.          9.8/13/  30.         27.3/13/  82.          9.4/13/  28.
  NOX BCKGRD METER/RANGE/PPM                    .8/ 2/   1.           .6/ 2/   1.           .6/ 2/   1.           .5/ 2/   1.

  DILUTION FACTOR                                46.01                 32.57                 12.28                 45.96
  HC  CONCENTRATION PPM                          10.                   12.                   16.                    5.
  CO  CONCENTRATION PPM                          46.                   32.                   22.                   21.
  CO2 CONCENTRATION PCT                          .24                   .37                  1.05                   .25
  NOX CONCENTRATION PPM                         22.1                  28.9                  81.5                  27.7

  HC  MASS GRAMS                                 1.74                  2.13                  2.78                   .81
  CO  MASS GRAMS                                15.99                 11.29                  7.65                  7.43
  CO2 MASS GRAMS                              1290.2                2009.6                5859.2                1353.9
  NOX MASS GRAMS                                12.53                 16.60                 47.53                 15.75
  FUEL KG (LB)                                  .533 (    1.17)       .898 (    1.98)      2.736 (    6.03)       .577 (    1.27)
  KW HR (HP HR)                                 1.06 (    1.43)       1.85 (    2.48)       6.65 (    8.92)       1.01 (    1.35)

  BSHC G/KW HR (G/HP HR)                        1.64 (    1.22)       1.15 (     .86)        .42 (     .31)        .80 (     .60)
  BSCO G/KW HR (G/HP HR)                       15.03 (  11.21)        6.11 (    4.55)       1.15 (     .86)       7.35 (    5.48)
  BSCO2 G/KW HR (G/HP HR)                    1212.62 ( 904.25)     1087.17 ( 810.70)     880.49 ( 656.58)    1340.64 ( 999.72)
  BSNOX G/KW HR (G/HP HR)                      11.77 (    8.78)       8.98 (    6.70)       7.14 (    5.33)      15.60 (   11.63)
  BSFC KG/KW HR (LB/HP HR)                      .501 (    .823)       .486 (    .799)       .411 (    .676)       .571 (    .939)

TOTAL TEST RESULTS 4 BAGS                            PARTICULATE DATA, TOTAL FOR 4 BAGS

  TOTAL KW HR (HP HR)          10.58 ( 14.18)            90MM FILTER
   BSHC    G/KW HR (G/HP HR)     .70 (   .53)               SAMPLE FLOW       SCM(SCF)                    1.274 ( 45.01)
   BSCO    G/KW HR (G/HP HR)    4.00 (  2.99)               MULTIPLIER FOR    G/TEST                       .940
   BSCO2   G/KW HR (G/HP HR)    994. (  741.)               MULTIPLIER FOR    G/KW HR (G/HP HR)            .0839 ( .0663)
   BSNOX   G/KW HR (G/HP HR)    8.74 (  6.52)               MULTIPLIER FOR    G/KG FUEL (G/LB FUEL)        .1981 ( .0899)
   BSFC   KG/KW HR (LB/HP HR)   .449 (  .737)
                                                          20 X 20 FILTERS
 PART. G/KW-HR (G/HP-HR) .39 (.29)                          SAMPLE FLOW      SCM(SCF)                    81.28 (2870.9)
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                                   TABLE F-8.ENGINE EMISSION RESULTS
                                                H-TRANS.                                                PROJECT NO. 11-5044-001

ENGINE  NO.D20                             TEST NO.D23-1  RUN1
ENGINE  MODEL   80 VOLVO DUALFUEL          DATE 11/10/80
ENGINE  9.6 L(586. CID) L-6                TIME !!!!!                                 DIESEL   EM-465-F
CVS NO.  10                                  DYNO NO.  5                                BAG CART NO.  1

BAROMETER 742.44 MM HG(29.23 IN HG)        RELATIVE HUMIDITY ,  ENGINE-56. PCT ,  CVS-45. PCT
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)      ABSOLUTE HUMIDITY 10.5 GM/KG( 73.6 GRAINS/LB)      NOX HUMIDITY C.F. 1.0000

BAG RESULTS
   BAG NUMBER                                    1                  2                  3
   BLOWER DIF P MM. H2O(IN. H2O)            680.7 (26.8)       680.7 (26.8)       680.7 (26.8)
   BLOWER INLET P MM. H2O(IN. H2O)          525.8 (20.7)       525.8 (20.7)       525.8 (20.7)
   BLOWER INLET TEMP. DEG. C(DEG. F)         51.7 (125.0)       51.7 (125.0)       51.7 (125.0)
   BLOWER REVOLUTIONS                          5695.              6008.              5693.
   TIME SECONDS                                272.3              287.7              272.6
   TOTAL FLOW STD. CU. METRES(SCF)          271.4 ( 9587.)     286.4 (10114.)     271.3 ( 9584.)

     HC  SAMPLE METER/RANGE/PPM             17.7/11/  18.      17.9/11/  18.      16.3/11/  16.
     HC  BCKGRD METER/RANGE/PPM              8.9/ 1/   9.       9.9/ 1/  10.       9.7/ 1/  10.
     CO  SAMPLE METER/RANGE/PPM             42.8/13/  40.      46.9/13/  44.      31.9/13/  29.
     CO  BCKGRD METER/RANGE/PPM               .3/13/   0.        .1/13/   0.        .1/13/   0.
     CO2 SAMPLE METER/RANGE/PCT             20.9/ 3/  .34      24.9/ 3/  .41      21.0/ 3/  .34
     CO2 BCKGRD METER/RANGE/PCT              2.8/ 3/  .04       2.8/ 3/  .04       2.8/ 3/  .04
     NOX SAMPLE METER/RANGE/PPM              8.9/13/  27.      11.3/13/  34.       9.9/13/  30.
     NOX BCKGRD METER/RANGE/PPM              1.3/ 2/   1.       1.3/ 2/   1.       1.3/ 2/   1.

     DILUTION FACTOR                           39.11              32.53              39.05
     HC  CONCENTRATION PPM                      9.                 8.                 7.
     CO  CONCENTRATION PPM                     39.                43.                28.
     CO2 CONCENTRATION PCT                      .30                .36                .30
     NOX CONCENTRATION PPM                     25.4               32.7               23.4

     HC  MASS GRAMS                             1.42               1.37               1.07
     CO  MASS GRAMS                            12.22              14.29               8.93
     CO2 MASS GRAMS                          1467.5             1910.8             1475.5
     NOX MASS GRAMS                            13.18              17.90              14.72
     FUEL KG (LB)                              .614 (   1.35)     .876 (   1.93)     .637 (   1.40)
     KW HR (HP HR)                             1.27 (   1.70)     1.98 (   2.66)     1.25 (   1.68)

     BSHC G/KW HR (G/HP HR)                    1.11 (    .83)      .69 (    .52)      .85 (    .63)
     BSCO G/KW HR (G/HP HR)                    9.61 (   7.16)     7.20 (   5.37)     7.13 (   5.32)
     BSCO2 G/KW HR (G/HP HR)                1154.28 ( 860.74)   963.21 ( 718.27)  1177.27 ( 877.89)
     BSNOX G/KW HR (G/HP HR)                  10.37 (   7.73)     9.02 (   6.73)    11.75 (   8.76)
     BSFC KG/KW HR (LB/HP HR)                  .483 (   .794)     .441 (   .726)     .508 (   .835)

TOTAL TEST RESULTS 3 BAGS                                     PARTICULATE DATA, TOTAL FOR 3 BAGS

   TOTAL KW HR (HP HR)           4.51 (   6.05)                    90MM FILTER
     BSHC    G/KW HR (G/HP HR)    .86 (    .64)                       SAMPLE FLOW      SCM(SCF)                  .877 ( 30.96)
     BSCO    G/KW HR (G/HP HR)   7.86 (   5.86)                       MULTIPLIER FOR   G/TEST                    .946
     BSCO2   G/KW HR (G/HP HR)  1077. (   803.)                       MULTIPLIER FOR   G/KW HR (G/HP HR)         .2098 ( .1565)
     BSNOX   G/KW HR (G/HP HR)  10.16 (   7.58)                       MULTIPLIER FOR   G/KG FUEL (G/LB FUEL)     .4449 ( .2018)
     BSFC   KG/KW HR (LB/HP HR)  .472 (   .775)
                                                                   20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .38 (.28)                                     SAMPLE FLOW     SCM(SCF)                  55.52 (1961.0)
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                                     TABLE F-9. ENGINE EMISSION RESULTS
                                                 H-TRANS.                                        PROJECT NO. 11-5044-001

ENGINE  NO.D20                               TEST NO.D23-2[illegible] RUN1
ENGINE  MODEL   30 VOLVO DUALFUEL            DATE 11/10/80
ENGINE  9.6 L(586. CID) L-6                  TIME :::::                          DIESEL   EM-465-F
CVS NO.  10                                    DYNO NO.  5                        BAG CART NO.  1

BAROMETER 742.44 MM HG(29.23 IN HG)          RELATIVE HUMIDITY ,  ENGINE-48. PCT ,  CVS-45. PCT
DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)        ABSOLUTE HUMIDITY 10.6 GM/KG( 74.3 GRAINS/LB)     NOX HUMIDITY C.F. 1.0000

BAG RESULTS
  BAG NUMBER                                        1                     2                     3
  BLOWER DIF P MM. H2O(IN. H2O)              680.7 (26.8)          680.7 (26.8)          680.7 (26.8)
  BLOWER INLET P MM. H2O(IN. H2O)            525.8 (20.7)          525.8 (20.7)          525.8 (20.7)
  BLOWER INLET TEMP. DEG. C(DEG. F)           51.7 (125.0)          51.7 (125.0)          51.7 (125.0)
  BLOWER REVOLUTIONS                            5694.                 6008.                 5694.
  TIME SECONDS                                  272.6                 287.7                 272.7
  TOTAL FLOW STD. CU. METRES(SCF)            271.4 ( 9587.)        286.4 (10116.)        271.4 ( 9587.)

  HC   SAMPLE METER/RANGE/PPM                18.6/11/  19.         17.1/11/  17.         14.2/11/  14.
  HC   BCKGRD METER/RANGE/PPM                 9.0/ 1/   9.          9.8/ 1/  10.          8.0/ 1/   8.
  CO   SAMPLE METER/RANGE/PPM                50.3/13/  47.         49.2/13/  46.         30.8/13/  28.
  CO   BCKGRD METER/RANGE/PPM                  .6/13/   1.           .4/13/   0.           .4/13/   0.
  CO2  SAMPLE METER/RANGE/PCT                21.3/ 3/  .34         25.5/ 3/  .42         21.5/ 3/  .35
  CO2  BCKGRD METER/RANGE/PCT                 3.2/ 3/  .05          2.8/ 3/  .04          2.8/ 3/  .04
  NOX  SAMPLE METER/RANGE/PPM                 9.2/13/  28.         12.0/13/  36.         10.5/13/  32.
  NOX  BCKGRD METER/RANGE/PPM                 1.5/ 2/   2.          1.4/ 2/   1.          1.4/ 2/   1.

  DILUTION FACTOR                               38.25                 31.71                 38.14
  HC   CONCENTRATION PPM                        10.                    8.                    6.
  CO   CONCENTRATION PPM                        46.                   45.                   27.
  CO2  CONCENTRATION PCT                        .30                   .37                   .31
  NOX  CONCENTRATION PPM                        26.1                  34.5                  30.2

  HC   MASS GRAMS                               1.55                  1.25                  1.00
  CO   MASS GRAMS                              14.52                 14.98                  8.53
  CO2  MASS GRAMS                             1471.7                1966.0                1518.6
  NOX  MASS GRAMS                              13.56                 18.92                 15.66
  FUEL KG (LB)                                  .629 (    1.39)       .900 (    1.98)       .657 (    1.45)
  KW HR (HP HR)                                 1.28 (    1.72)       1.97 (    2.65)       1.25 (    1.68)

  BSHC  G/KW HR (G/HP HR)                       1.21 (     .90)        .63 (     .47)        .80 (     .60)
  BSCO  G/KW HR (G/HP HR)                      11.34 (    8.46)       7.59 (    5.66)       6.80 (    5.07)
  BSCO2 G/KW HR (G/HP HR)                    1149.38 (  857.09)     995.59 (  742.41)    1211.62 (  903.51)
  BSNOX G/KW HR (G/HP HR)                      10.59 (    7.90)       9.58 (    7.14)      12.50 (    9.32)
  BSFC  KG/KW HR (LB/HP HR)                     .491 (    .807)       .456 (    .749)       .524 (    .862)

TOTAL TEST RESULTS 3 BAGS                              PARTICULATE DATA, TOTAL FOR 3 BAGS

  TOTAL KW HR (HP HR)            4.51 (   6.05)           90MM FILTER
   BSHC    G/KW HR (G/HP HR)      .84 (    .63)              SAMPLE FLOW       SCM(SCF)                   .881 ( 31.11)
   BSCO    G/KW HR (G/HP HR)     8.44 (   6.29)              MULTIPLIER FOR    G/TEST                     .941
   BSCO2   G/KW HR (G/HP HR)    1097. (   820.)              MULTIPLIER FOR    G/KW HR (G/HP HR)          .2088 ( .1557)
   BSNOX   G/KW HR (G/HP HR)    10.68 (   7.96)              MULTIPLIER FOR    G/KG FUEL (G/LB FUEL)      .4307 ( .1954)
   BSFC    KG/KW HR (LB/HP HR)   .485 (   .797)
                                                          20 X 20 FILTERS
PART. G/KW-HR (G/HP-HR)  .36 (.27)                           SAMPLE FLOW     SCM(SCF)                   55.63 (1965.0)
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